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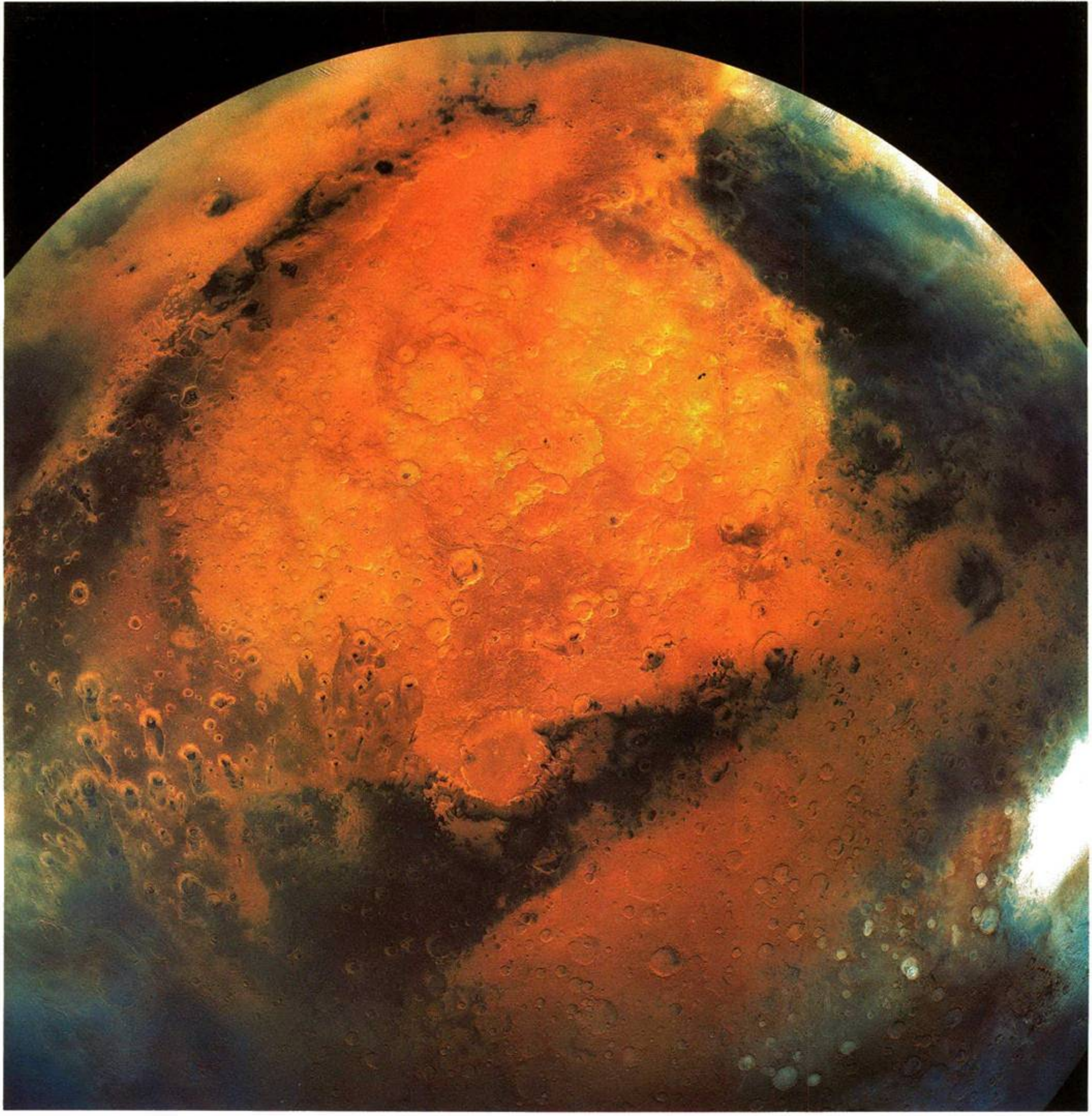
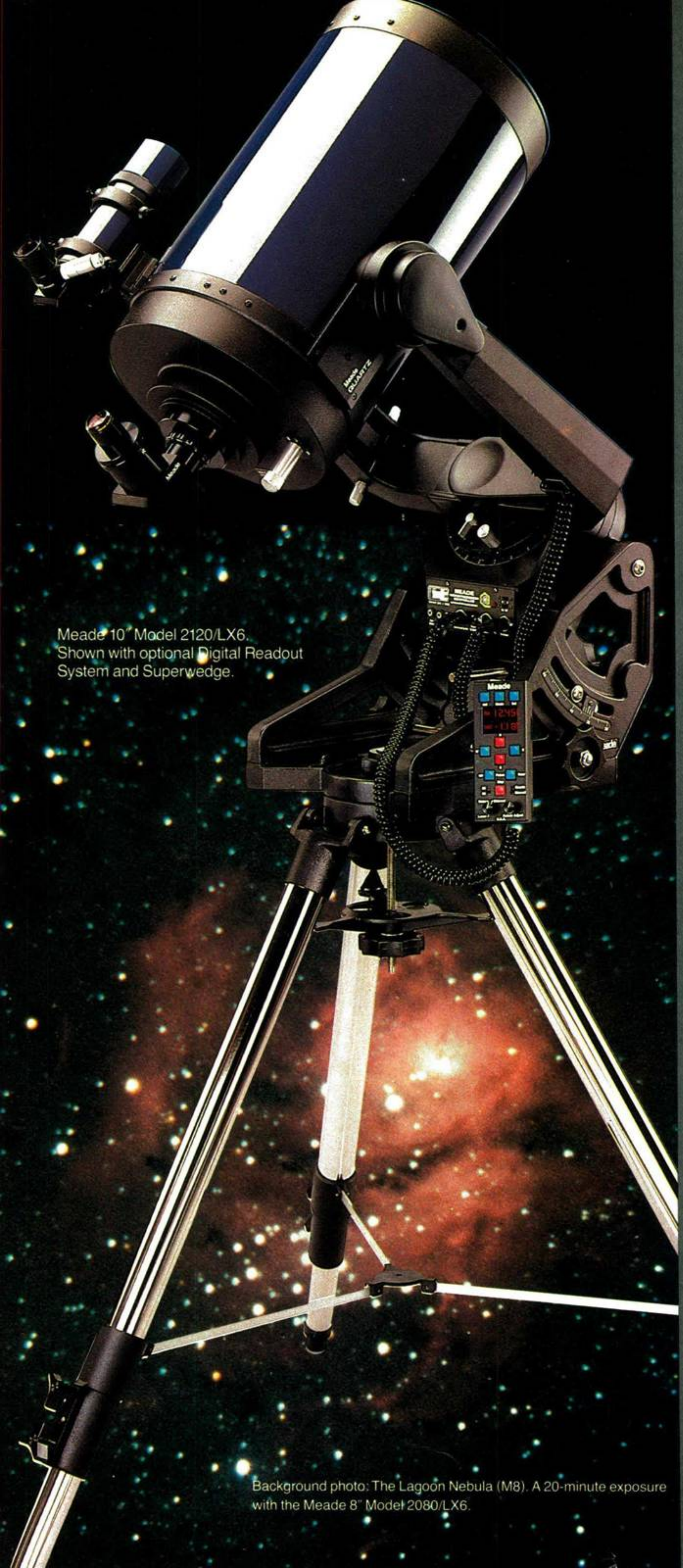


Searching for Water on Mars



Meade 10" Model 2120/LX6. Shown with optional Digital Readout System and Superwedge.

Background photo: The Lagoon Nebula (M8). A 20-minute exposure with the Meade 8" Model 2080/LX6.

Meade® 10" 2120/LX6: Number One Worldwide.

Now Available with the Meade Superwedge™ for Even More Stability!

The Meade 10" Wide-Field Model 2120/LX6 is now the World's most popular large-aperture Schmidt-Cassegrain. Meade 10" 2120 models, in fact, continue to outsell most competing *8"* Schmidt-Cassegrain models!

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■ **Fast f/6.3 Schmidt-Cassegrain Optics**—*Individually hand-matched, diffraction-limited optics* that yield wide fields of view and fast photo exposure times not possible with conventional f/10 optics.

■ **Multi-Function Electronic Command Center**—The ECC hand controller puts virtually every telescope function at your fingertips:

☐ *2X Drive Correction Speed* for precise electronic corrections during astrophotography.

☐ *8X Scanning Speed* for rapid electronic centering of the image, or for roving about a sky region at 8X the sidereal speed. Add the optional Declination Motor for dual-axis capability at 2X or 8X speeds.

☐ *Optional Digital Readouts:* Find faint objects in seconds using the Meade Digital Readout System (DRS). The DRS adds easily and quickly to 8" and 10" LX6 models and permits precise monitoring of telescope position in RA and Dec, directly from the hand controller.

■ **Advanced-Design Power Panel**—Virtually every modern electronic accessory can be plugged into the telescope's power panel. Accessories including the Meade CAT Computer Aided Telescope system, #1200A Electric Focuser, Digital Readout System, Illuminated Reticle Eyepiece, and more.

■ **A Specifications Listing** that includes 9 x 60mm Polar Illuminated Viewfinder, 2" Diagonal Mirror (itself a $200 option on competing models), Multi-Coated Optics Group, and Super Plössl 26mm eyepiece.

See your Meade dealer for full details on the 10" Model 2120/LX6—the telescope that's Number One among serious amateurs worldwide.

■ **NEW! Meade Superwedge**—The equatorial wedge included as standard equipment with the 2120/LX6 is satisfactory for all normal applications of the telescope. Observers who require extreme stability in the most demanding applications may specify the new Superwedge in place of the standard wedge, at additional cost. The Superwedge includes microfine azimuth and elevation controls, and reduces telescope damping time by about 80%.

Add the Superwedge to your Meade 10" Schmidt-Cassegrain.

The Meade Superwedge is available separately for retrofitting to existing Meade 10" Schmidt-Cassegrain telescope Models 2120, 2120/LX3, 2120/LX5, and 2120/LX6. Call or write your Meade dealer for details.

Ever expect to see the Great Nebula in Orion (M42) as a glowing blue-green ember? Or resolve the Hercules globular cluster (M13) to the core? Or observe the dust lanes and spiral structure in the Whirlpool Galaxy (M51)? Not just photographically, but **visually.** You can, and can afford to, observe these and countless hundreds of other objects as you've never seen them before, with a Meade Deep-Space DS-10 or DS-16 telescope.

Consider the possibilities in astrophotography: With exposures of *less than 15 minutes,* capture the glowing yellow-red detail of the Ring Nebula (M57), including the 15th-magnitude central star; or the complete red, blue, and green structure of the Orion Nebula, including the diffuse outer loop; or the fiery-red gaseous detail of the Omega Nebula (M17). Combining giant apertures with fast f/4.5 focal ratios, the Meade DS-10 and DS-16 permit photo exposure times so short even a beginner can obtain exciting results.

Each DS-10 and DS-16 is supplied as a complete operating telescope. Included as standard equipment on both telescopes are the complete optical tube assembly, *equatorial* mount, low-profile pier and tripod legs. Electric motor drives, as well as a long list of equipment for advanced applications, are available optionally.

At **$895** for the DS-10 and **$1695** for the DS-16, Meade Deep-Space telescopes offer giant apertures at very reasonable price levels. Order one today from your Meade dealer—and observe or photograph deep-space as you never thought possible.

SPECIFICATIONS:

Meade DS-10: 10″ f/4.5 Reflecting Telescope — Includes null-figured, diffraction-limited Pyrex parabolic primary mirror and matching (2.60″ M.A.) elliptical flat secondary; #67 rack-and-pinion focuser; MA 25mm (46X) coated eyepiece; Sonotube 12″ I.D. x 46″ long, sealed and attractively Zolatone coated; all-metal, precision-machined equatorial mount, with ultrasmooth Nylon bearings and 1″ solid steel shafts; low-profile pier and tripod legs. **$895**

Meade DS-16: 16″ f/4.5 Reflecting Telescope — Includes null-figured, diffraction-limited, Pyrex parabolic primary mirror and matching (4.00″ M.A.) elliptical flat secondary; flotation mirror cell; #67 rack-and-pinion focuser; MA 25mm (73X) coated eyepiece; Sonotube 18″ I.D. x 68″ long, sealed and attractively Zolatone coated; all-metal, precision-machined equatorial mount, with ultrasmooth Nylon bearings, 1½″ solid steel shafts, and 5″ dia. polar thrust surface; low-profile pier and tripod legs. **$1695**

Optional Features — #787 Electric Motor Drive (DS-10); #897 Worm Gear Motor Drive (DS-16); Sealmaster Ball Bearing polar axis (DS-16); 6 x 30mm and 8 x 50mm Viewfinders; Manual Declination Controls; Single- and Dual-Axis Drive Correctors; 2.4″ and 3.1″ Photo-Guide Telescopes; Giant #680 Focuser for 1¼″ & 2″ O.D. eyepieces; Setting Circles.

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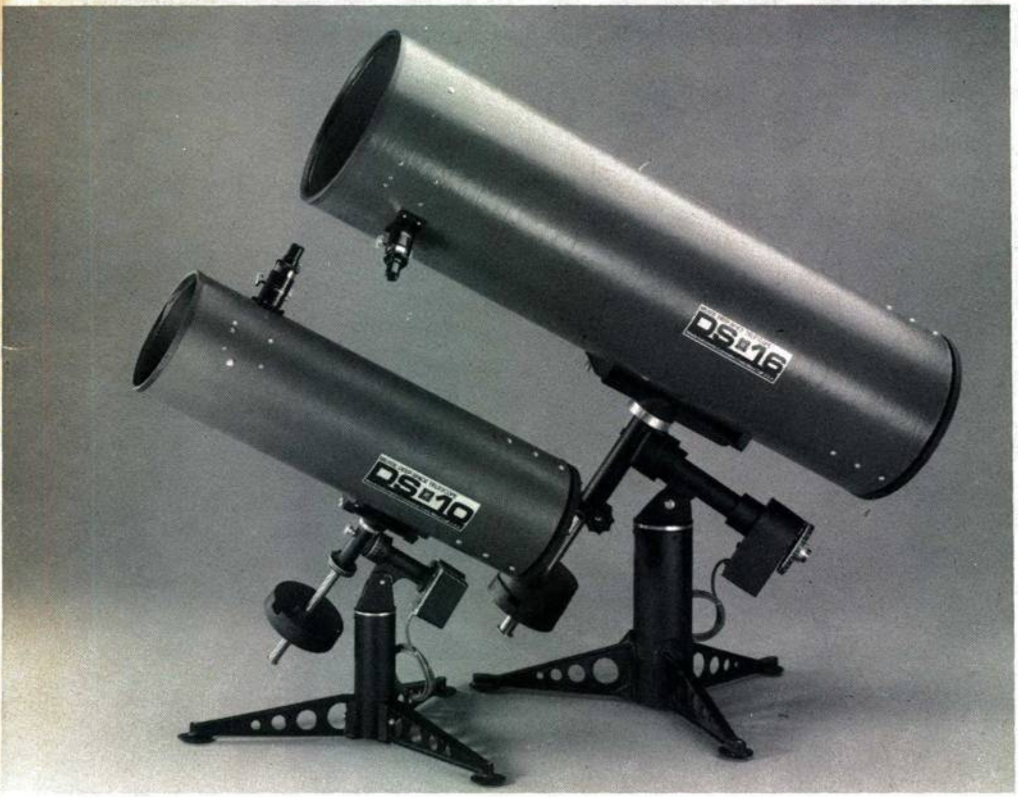

Meade DS-10 and DS-16, shown with optional motor drives, setting circles, giant focusers.

Meade DS-16 Astrophotos:
(top) Southern region of the Andromeda Galaxy (M31);
(lower) The Horsehead Nebula. Both photos by Paul Roques.

Dealer Locations and Assistance

For your nearest Meade dealer location, or for free telescope information and assistance, call Meade Instruments toll-free from anywhere in the continental U.S.A. (except California): **1-800-854-7485.** From all other areas, including California, call direct (714) 556-2291.

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Includes 6 separate catalogs and bulletins on the entire range of Meade astronomical telescopes, Series 4000 eyepieces, and accessories.

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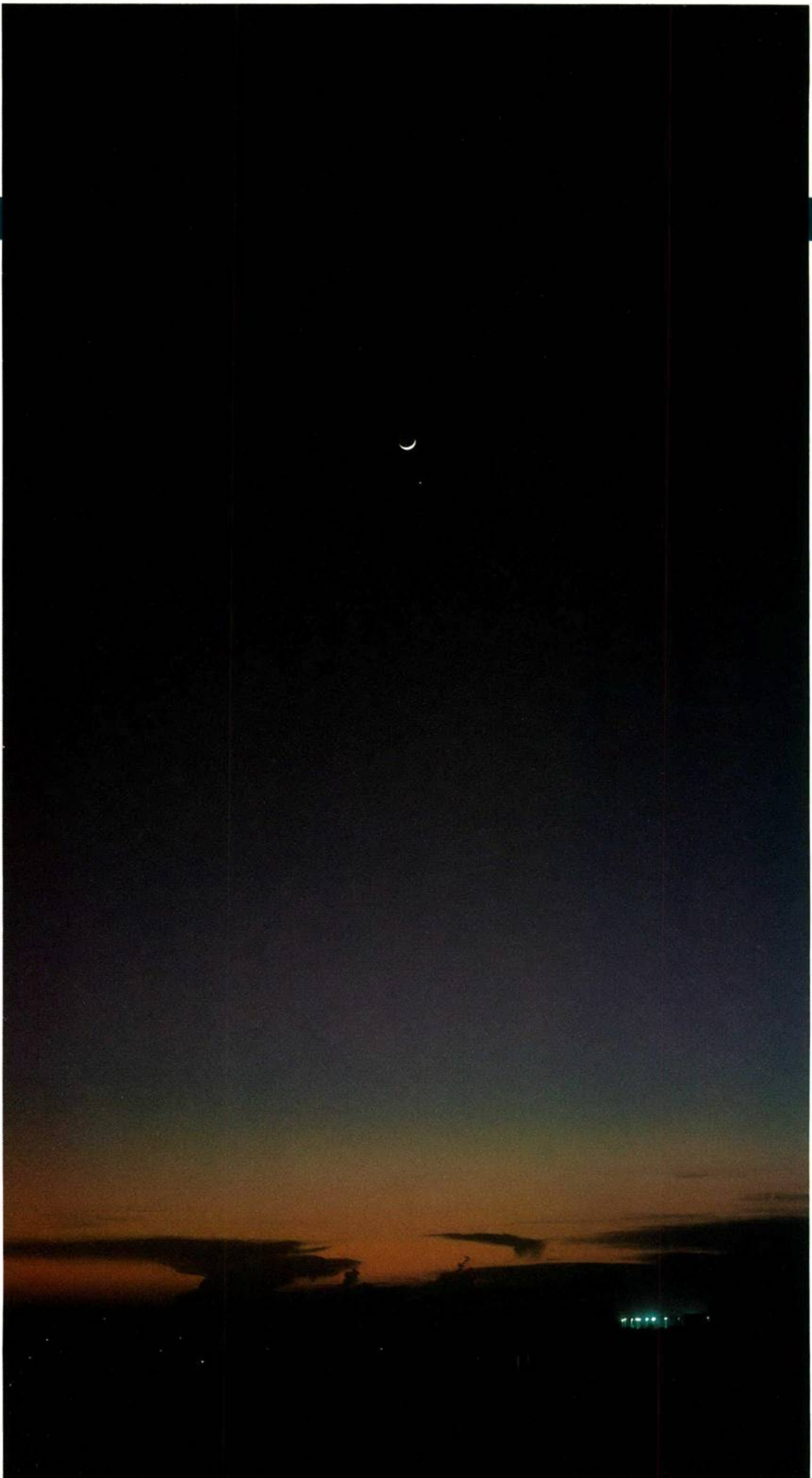
ON THE COVER: Eroded by flowing water and wearing a cap of ice, today's Mars may also harbor vast reserves of water frozen beneath the ground. (See page 20.)



VENUS AND THE MOON formed a striking pair over Miami, Florida, in January 1988. Visible close to the horizon is Mercury's faint orange light. Photo by David L. Rights.

ASTRONOMY®

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ASTRONOMY (ISSN 0091-6358) is published monthly by Kalmbach Publishing Co., 1027 North 7th Street, Milwaukee, WI 53233. Copyright © 1989 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Second-class postage paid at Milwaukee, WI, and additional mailing offices. POSTMASTER: Send address changes to ASTRONOMY, 1027 North 7th Street, Milwaukee, WI 53233. Questions about subscriptions and product orders: **(414) 272-2060** weekdays, 8:30 a.m. - 4:45 p.m. Allow six to eight weeks for new subscriptions and changes of address. New subscriptions start with current issue. Subscription price: 1 year, $24. All foreign: add $9 per year; please remit in U.S. funds. Send editorial and business inquiries and submissions to the address above. Telephone: (414) 272-2060. Not responsible for unsolicited materials. ASTRONOMY is indexed in *The Reader's Guide to Periodical Literature*. Microfilms of ASTRONOMY available from University Microfilms, Inc., 300 North Zeeb Road, Ann Arbor, MI 48106. Printed in the U.S.A.

Behind the Scenes

IT'S MOVE TIME FOR ASTRONOMY

Again and again, ASTRONOMY has outgrown its quarters. In the sixteen years since Volume 1, Number 1 was mailed to 12,000 charter subscribers, ASTRONOMY has grown into the largest circulation astronomy magazine in the world. Now, with eleven other Kalmbach magazines, ASTRONOMY is moving from downtown Milwaukee to new and larger offices west of the city in Waukesha, Wisconsin.

Back in January 1976, when I started at ASTRONOMY, the editorial staff worked in a room that had been a beauty parlor. Pipes stuck out of the wall behind my desk where sinks had been attached. Henry Phillips, Kathy King, and I used filing cabinets to divide the room where we pounded out stories on portable typewriters.

But ASTRONOMY was growing. In 1977 we moved to a low-rent downtown office building where we had carpeting on the floor, lamps for our desks, and shelves for our books. In six short years we surpassed the competition's circulation, founded *Odyssey* and *Telescope Making* magazines, and once again outgrew our office space.

The move to 625 St. Paul Avenue in 1983 was a big one for us. We rehabilitated a sleazy structure, which had once housed a bar featuring mud wrestling, into a bright, modern, and airy publishing environment. When Kalmbach purchased AstroMedia, we moved across town to the "penthouse suite" on the eighth floor of Kalmbach's office building.

Kalmbach is today in the midst of rapid expansion, spurring the move to a new 81,000-square-foot facility. All of the Kalmbach hobby publications — ASTRONOMY, *Odyssey*, *Telescope Making*, *Deep Sky*, the two original railroad magazines and two new railroad quarterlies, *Fine Scale Modeler*, and three miniatures publications — will be together under one roof.

After July 15, please use our new address: ASTRONOMY, Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Our new phone number is (414) 796-8776.

When you're in the area, we'd love to show you our offices. We're right near the intersection of I-94 and Highway 18, about seventeen miles west of Milwaukee in the Crossroads Corporate Center. Drop in and say hello.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

ASTRONOMY

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(800) 558-1544

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Adpress, Inc., New York, NY 10016
(212) 679-1710

U.S. Newsstand Distribution
I.C.D., The Hearst Corp., New York, NY 10019

Canadian Newsstand Distribution
Telemedia Dist., Toronto, Ontario M4S 3B3

World Newsstand Distribution
Boarts International, Inc., New York, NY 10019

Letters

The Power of Small Scopes

I cringe whenever I read about being able to view a given object "even with a 4-inch telescope" (page 92, May 1989). I have a 4½-inch Bausch & Lomb Newtonian, and with it I have seen 120 of the sky's most beautiful objects (thanks to Richard Berry's *Discover the Stars*, David Eicher's *The Universe from Your Backyard*, and Ronald Morales' *Amateur Catalog*).

One day I hope to have an 8-inch scope, but I'll never sell my 4-inch Newtonian! — *Richard R. Didick, Norton, Massachusetts*

Cosmic Evolution

I have been a reader of ASTRONOMY for many years and I consider it an excellent magazine. However, I must raise strong objection to your recent Viewpoint article, "The Cosmological Imperative," by Eric Chaisson (February 1989).

Astronomical thinking has been on a collision course for some time now due to the systematic removal of God and Man from any discussion of astronomical problems. The Big Bang, for example, may indeed have been the beginning of our universe, but by itself the theory explains nothing. A universe composed entirely of contingent beings could not have brought itself into existence.

This denial of God leads to the form of gee-whiz mumbo jumbo that characterized Chaisson's article. I cite one example: "Darwinism started a revolution by freeing us from a belief that humans basically differ from other life forms." This is perhaps the most arrogant expression ever to disgrace your magazine.

If Mr. Chaisson really believes there is no fundamental difference between himself and the lower animals, I suggest he visit Cambodia and then Chicago and meditate on the proposal that there is no difference between the slaughter houses in Chicago and the slaughter fields in Cambodia. — *Peter Andre, Seattle, Washington*

Southern Aligning Tip

I hope this letter will spare my fellow observers in the Southern Hemisphere some of the frustration I experienced when I started observing.

My local library has a fairly good selection of books on astronomy. The problem is none of these books divulge the secret of how to align accurately on the south celestial pole. If a book even makes reference to Octans (the constellation the pole lies in), it usually briefly states, "There are no stars above 5th magnitude in Octans." While this may be true, it is no help in polar aligning.

DEAR MR. NAGLER:

Several years ago, I purchased a 10" Schmidt-Cassegrain telescope. On this new instrument, I carefully compared the performance of the most respected brands of eyepieces before concluding that the **Tele Vue** Plössls were giving me the best views. Along with 4 of your Plössls (55, 26, 17 and 13mm) and your 2.5x Barlow, I bought a Giant Off-Axis Guider, which I frequently use as a telecompressor. Although I have always been pleased with your eyepieces, there are limits to just how much a long-focal-length telescope can be telecompressed! ■

For over three years, I have wanted a second instrument for rich-field observing and photographing. Although your **Renaissance** is most impressive, it just wasn't quite the instrument I wanted and the **Oracle** was a bit too small. Then came **Genesis.** Knowing what a stickler you are for details in both design and production, plus my total satisfaction with your eyepieces; sight unseen, I bought a **Genesis** based solely on those facts and your ads in the magazines. ■

I took delivery of my **Genesis** at the Texas Astronomical Society's meeting on 7/22/88. Even with all the light pollution in that North Dallas parking lot, my new **Tele Vue** 32mm Wide Field eyepiece, at less than 16x, clearly resolved Saturn's rings as separate from the disc. When a friend asked to try his 12 mm Nagler-II with his 3x Barlow, I knew I had bought a "winner." The Cassini Division was as sharply defined as I have ever seen it plus the surface and ring detail was second only to a view I once saw under a Texas Star Party's dark skies through a nearly $20,000, 10.7" f/15 Maksutov! ■

The reason for this letter is simple. I have now had my first opportunity to take my new **Genesis** out to the T.A.S.'s dark-sky observing site (100 miles north of Dallas). In short order, the **Genesis** had attracted a group of experienced observers (most holding full Messier Certificates) away from their larger telescopes. Simply, **Genesis** stole the show! Except for an occasional comparison view, my 10" Schmidt-Cassegrain sat idle because I was seeing far greater clarity and detail with my new **Genesis.** Although I had with me a full set of filters (Deep Sky, U.H.C., O-III and H-β), none were ever used. ■

While I had anticipated a gorgeously resplendent Double Cluster, it was truly more dazzling than I expected. But, some real surprises lay ahead. Take M-33 in Triangulum: 4" just isn't enough aperture for such a diffuse spiral, right? WRONG! With the 32mm Wide Field, I was seeing tremendous detail in a galaxy over 1/3 the width of the field. I could write paragraphs describing a California Nebula covering half the field plus all the glorious sights through Sagittarius and Scorpius like the Lagoon, Trifid and M-21 all in the same field; or, four gleaming globulars, M-22 & 28 with NGC-6638 & 6642. ■

While the Great Andromeda Galaxy (M-31) spread across more than 2/3 of the field, we were all alternating time at the eyepiece, trying to see who could count the most dust lanes. It was more beautiful than even the photographs from the leading observatories. I have never seen M-110 appear as large relative to M-31. One observer even held his hand in front of the eyepiece and suggested that we try observing a projected image! While that may have been beyond even **Genesis'** capability, it does prove we were looking at no dim M-31. There was a debate over which eyepiece provided the better view: the 13mm Nagler's greater contrast and detail or the 32mm Wide Field's greater coverage. Each outperformed the other in its own way and both provided splendid views. ■

All night, comments from seasoned observers included a thesaurus-full of one word expletives of praise, wonder and astonishment. While glued to the eyepiece, other comments included: "... but this is ONLY a 4-inch" to "Boy! You sure made no mistake in buying this one" and "Oh, No!... How am I ever going to make my wife see the need?". One observer even yelled to a friend across the field, "Get over here if you want to see what Rich Field is SUPPOSED to look like." Personally, I can hardly wait to start taking astrophotos with it. ■

In case you could have possibly missed my point: I am totally enthralled with my new **Genesis.** Mr. Nagler, what you have created with your **Renaissance** and **Genesis** telescopes has filled a void, beyond binoculars and yet still permitting the beauty of deep sky objects to be viewed 'in context' without resorting to the usual solution of over-magnification that reveals detail at the expense of sacrificing perspective. ■

Because our dark sky observing location attracts late-night dewing and humidity, I appreciate your design consideration of including the fluorite element as a totally internal component, inaccessible to dew, condensation or scratches. ■

It would have been impolite of me not to write and tell you just how much of a Big Bang your **Genesis** telescope has already created in my deep sky observing. ■

Appreciatively yours,

Kent E. Ledlow

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I have observed a beautiful configuration of three stars between 5th and 6th magnitude that serve as a signpost for aligning on the pole. Tau, Sigma, and Chi form a triangle. If you bisect the triangle through Sigma and move about 1° south, you'll arrive exactly at the pole. *—Joseph Myers, Auckland, New Zealand*

We Will Reach the Stars

I must take issue with the comments made in "The Amateur's Universe" (Viewpoint, April 1989). It seems that Mr. Teece and Mr. Newton feel that humanity is guilty of some great crime by developing a technological civilization.

Their comment that amateurs are attracted to observing starclouds and galaxies because of their eternal inaccessibility is absurd. Rather, the stars are a symbol of hope for the future. We gaze at them because we dream that one day we will reach them. *— J. D. Law-Green, Leeds, United Kingdom*

***Solar Max* Boost**

It is hard to believe that NASA will let the *Solar Max* satellite fall to destruction. The satellite originally cost over $200 million to build, and today it would cost much more to be replaced.

NASA says it is unable to save *Solar Max*. This seems rather strange. The space shuttle just spent five days in orbit taking pictures of Earth and incubating chicken eggs. Couldn't NASA arrange for the shuttle to match orbits with *Solar Max* and boost it to a higher orbit? *— Tom Abbott, Muskogee, Oklahoma*

Corrections

In "Equipped for Safe Solar Viewing" by Richard Hill (February 1989), the reference to the two filter manufacturers does not constitute endorsement by the author.

In the notice for *Cauldrons in the Cosmos* by Claus E. Rolfs and William S. Rodney (Astronomy Books, April 1989), published by the University of Chicago Press, the price listed was incorrect. The correct prices are $34.95 for paperback (ISBN 0-226-72457-3) and $74.95 for hardcover (ISBN 0-226-72456-5).

The photograph on page 92 (bottom right) of the July 1989 issue was taken by Bill Price, not Michael Sandras.

ASTRONOMY welcomes comments, suggestions, corrections, and additional information on articles and astronomy in general. Send your letters to: ASTRONOMY Letters, 1027 North 7th Street, Milwaukee, WI 53233. Letters may be edited for length or clarity. ☐

Viewpoint

THE UNIVERSE AS AFTERTHOUGHT

by Martin O. Harwit, director of the Smithsonian Institution's National Air and Space Museum, Washington, D.C.

Once you strip away the glamour that surrounds astronomical research — scientists peering relentlessly into space to uncover the secret workings of the universe — you find that in actuality the bulk of astronomers' time is occupied with studying the nature of their instruments rather than the nature of the universe.

The reason for this is simple. The interesting observations astronomers undertake today involve faint, distant sources or barely discernible features. These observations require that astronomers stretch the capabilities of their instruments to the very limit. The astronomer in search of truly novel results always works at the extreme edge of his instruments' performance, an edge that also defines the realm of his greatest uncertainty.

Astronomers spend far more time studying their instruments than the universe.

If an astronomer has to spend three hours on the telescope in order to register a feeble signal from a distant source, how does he know that this signal is real? How can he be sure that the telescope, if it had been pointed at an empty portion of the sky for three hours, would not have registered an equally weak but spurious signal? Such signals, called noise by astronomers, could be caused by a peculiar drift of the instrument's electronics, a faint atmospheric glow, or some other unanticipated effect.

Noise is the response that any measuring device registers even when no signal is incident. Sometimes a part of the noise can be explained and even minimized. But an irreducible noise level always persists for any apparatus, a consequence of the instrument's temperature. The temperature causes electrons to move about randomly in the electronic circuits that normally detect radiation arriving from an astronomical source. Because those electrons produce electrical currents identical to the currents produced by radiation arriving through the telescope, it becomes quite uncertain just how much radiation actually has been detected.

One of the major astrophysical discoveries of the century — the microwave background radiation produced by the Big Bang — was reported in a paper devoted to a description of an astronomical instrument and the measurement of noise. In the paper, titled "A Measurement of Excess Antenna Temperature at 4080 Megacycles Per Second" and published in the *Astrophysical Journal* in 1965, Arno Penzias and Robert W. Wilson discussed noise measurements conducted on their horn antenna at the Bell Telephone Laboratories in Holmdel, New Jersey.

Penzias and Wilson were unable to remove a certain degree of noise, or an antenna temperature producing that noise, from their instrument. "This excess temperature is, within the limits of our observations, isotropic, unpolarized, and free from seasonal variations (July 1964-April 1965)," they wrote.

That simple conclusion, however, was the result of an enormous amount of routine, painstaking calibration. The only way to tell whether a weak signal registered by an instrument is real (cosmic) or false (instrumental, atmospheric, etc.) is to repeat the observation under a wide variety of conditions in order to eliminate the many potential sources of error.

Penzias and Wilson had to carefully survey much of the sky to make sure the signal was isotropic (of equal strength in all directions) and not arriving from a large number of individual sources randomly distributed across the sky. They also measured the signal for ten months to confirm that it stayed constant in strength from day to day.

The two scientists were unable to explain this excess noise, except to note "a possible explanation" offered by four other authors in a companion article. That article suggested that the origin of the noise might be microwave radiation remaining from, and direct evidence for, the explosive origin of the universe, a discovery for which Penzias and Wilson later shared the Nobel Prize.

An astronomer spends far more time studying the peculiarities of his instruments and potential sources of error than observing the celestial sources of primary interest. The universe is merely what's left over, an afterthought, when all the nuisance factors have been eliminated from an instrumental measurement and its implied observational result.

That's just the way our knowledge of the universe happens to grow. ☐

HERE COMES THE SUN

Prepare for sunspot maximum in comfort and safety

Photo by John Sanford

Solar astronomy when done correctly can be one of the most rewarding forms of observational astronomy. High quality safe solar filters for many telescopes, like refractors and reflectors, have been hard to come by. Those available sometimes posed hazards to the viewer. With this in mind, Celestron is proud to introduce Solar Skreen® solar filters: SAFE solar filters specifically designed for our complete line of telescopes.

The filters, which transmit .001% of visible light, allow direct observation of the Sun. With them you can see Sunspots as they transit the solar disk and mottled areas known as granules. In addition to reducing the intensity of the Sun's visible light, they also block 99.999% of invisible infrared light providing complete viewing comfort and safety. Ideal for solar photography!

A precision engineered, strong aluminized Mylar polyester film is used to make these filters. A layer of aluminum is vacuum-deposited on one surface of each of the dual sheets of Mylar that make up this filter. These two surfaces are placed against each other to protect the aluminum from scratches and other abuses. The Mylar is very thin, about .0003" which is comparable to 1/10th the thickness of a human hair. Because it is so thin, it offers superior performance compared to thicker Mylar or window glass filters. Mylar filters are also less expensive than ordinary glass filters. (The Solar Skreen® solar filter is covered under U.S. Patent #3,897,140.)

With Solar Skreen® filters, the solar image will appear different since with its aluminum coating, the solar image appears as a cool, comfortable pale blue color. A true color image can be produced with the appropriate orange eyepiece correction filter (#21 or 23A).

Solar activity is already on the rise. And with the maximum peak just a few years away, things will only get better. Get ready now for the July 11, 1991 and May 10, 1994 solar eclipses!

- Filters for all current Celestron Schmidt-Cassegrains, refractors, Newtonian reflectors and C90's
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- Perfect for visual or photographic observations
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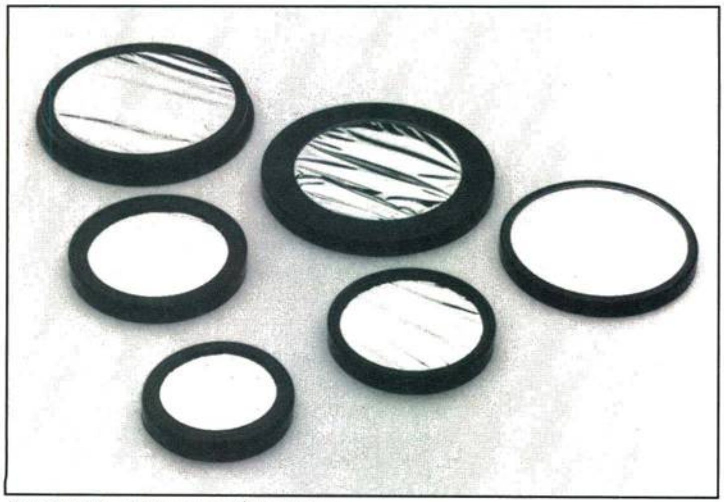

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EARTH GAINS A NEIGHBOR

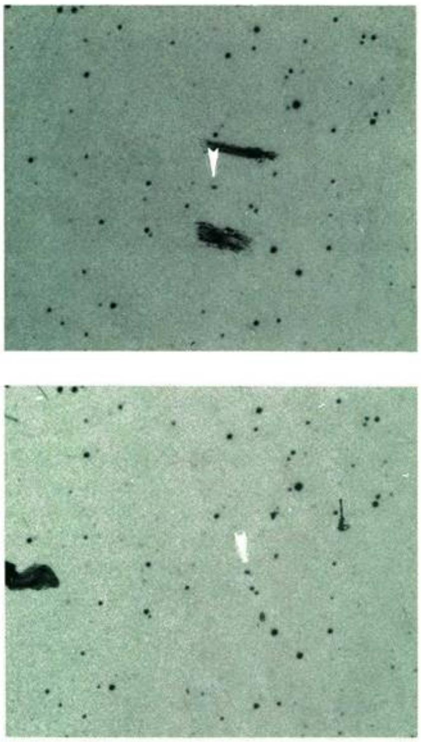
"That was a close call!" said Northern Arizona University astrogeologist Henry Holt of his latest discovery. On March 31, 1989, Holt discovered an asteroid on a pair of plates made with the 18-inch Schmidt telescope at Palomar Mountain, California. Hundreds of such asteroids are routinely discovered using big Schmidt telescopes, but this one — designated 1989 FC — was different. At first the asteroid didn't appear different. It was simply a 12th-magnitude smear of light in the constellation Coma Berenices. However, at the end of the first week of April, Holt deduced that this object had passed extremely close to Earth a week before its discovery.

"The asteroid passed within 450,000 miles of Earth on March 23," said Holt. "Although that sounds like a great distance, in cosmic terms it's not — only about twice the distance to the Moon." Other close approaches include the passes of Comet Lexell in 1770 (1.4 million miles), asteroid Hermes in 1937 (490,000 miles), and Comet IRAS-Araki-Alcock in 1983 (2.9 million miles).

Had asteroid 1989 FC hit Earth, it would have been a catastrophe unparalleled in human history. According to Bevan French, advanced program scientist for NASA's Solar System Exploration Division, the asteroid probably measures about half a mile across and orbits the Sun in a period of about a year, travelling at an average velocity of just under 50,000 miles per hour.

"If the asteroid had struck Earth," said French, "the impact would have been equivalent to the explosion of 20,000 one-megaton hydrogen bombs. That would leave a crater between five and ten miles wide and a mile deep." Had the asteroid landed in an ocean, said French, the destruction would have been far worse. "Depending upon the depth of the water, angle of entry, and size and speed of the object, it could have created tidal waves several hundred meters high."

After breathing a collective sigh of relief, astronomers set their minds toward the future of Earth's new neighbor. The asteroid moves about the Sun in a highly elliptical, year-long orbit that brings it close to Earth only every twenty years or so. "Sooner or later," said Holt, "1989 FC should collide with Earth, the Moon, or Mars — it's just a matter of time." In May astronomer Edward Bowell of Lowell Observatory calculated the asteroid's orbit to learn when it might next pass close to Earth. "Until a better orbit becomes available," said Bowell, "it is not possible to say when the next close approach to Earth will occur, although the roughly determined period of 1.045 years indicates about eleven or twenty-two years from now." Bowell and Brian Skiff, another Lowell astronomer, believe the next very close approach of 1989 FC will take place in the year 2012.



THIS DIM STREAK OF LIGHT, actually a half-mile-wide asteroid, narrowly missed Earth last March. Northern Arizona University astrogeologist Henry Holt found the asteroid on photos made 57 minutes apart on March 31.

PLENTY OF PULSARS YET TO BE DISCOVERED

At this time, five radio pulsars are known to exist in globular clusters in our Galaxy. But if a team of astronomers is correct, these five may be the first of thousands yet to be discovered.

Ramesh Narayan of Steward Observatory at the University of Arizona made the prediction about pulsars at the American Physical Society meeting in Baltimore this May. Narayan and collaborators Shrinivas Kulkarni of the California Institute of Technology and Roger Romani of the University of California, Berkeley, estimate that there may be a couple of thousand and perhaps as many as ten thousand undiscovered radio pulsars.

"Such a large number of pulsars raises intriguing questions regarding the origin of these systems," said Narayan. "Standard ideas on how these pulsars formed can explain only a hundredth of the pulsars we think are out there."

Pulsars are swiftly rotating neutron stars that emit focused beams of radio radiation from both magnetic poles. The beams sweep across space each time the star rotates. If one of the poles happens to be oriented toward Earth, observers receive a regular, pulsating signal.

Pulsars are found throughout the Galaxy, but those found in globular clusters are particularly interesting because they rotate very rapidly, anywhere between 10 and 300 times per second. These pulsars are called "recycled pulsars" because their rotation rates are believed to be increased by the gravitational interaction with a companion star. Gas pouring from the companion on to the magnetic poles of the denser neutron star adds mass and energy that, in effect, increases the spin rate.

As the neutron star is being "spun up," the binary system emits bright x-rays. Thus astronomers look for and identify incipient radio pulsars by their bright x-ray emission. Nearly one hundred bright x-ray sources are known in our Galaxy, many of which have been identified as pulsars in the making.

Narayan's group, however, predicts that there are not enough known x-ray sources to account for all recycled pulsars. X-ray sources are typically very bright and easy to detect, even at great distances. Nevertheless, astronomers see less than a dozen bright x-ray sources in globular clusters.

In contrast to x-ray sources, radio pulsars are very faint. By studying the distribution of pulsar luminosities throughout the Galaxy, Narayan has developed methods by which he can estimate the total number of pulsars from the few that have been discovered. By applying this method to the globular cluster pulsars, Narayan concludes that the five radio pulsars found in globular clusters so far *are just the tip of* the iceberg. "The calculations indicate that there are actually thousands of pulsars in these clusters," he said.

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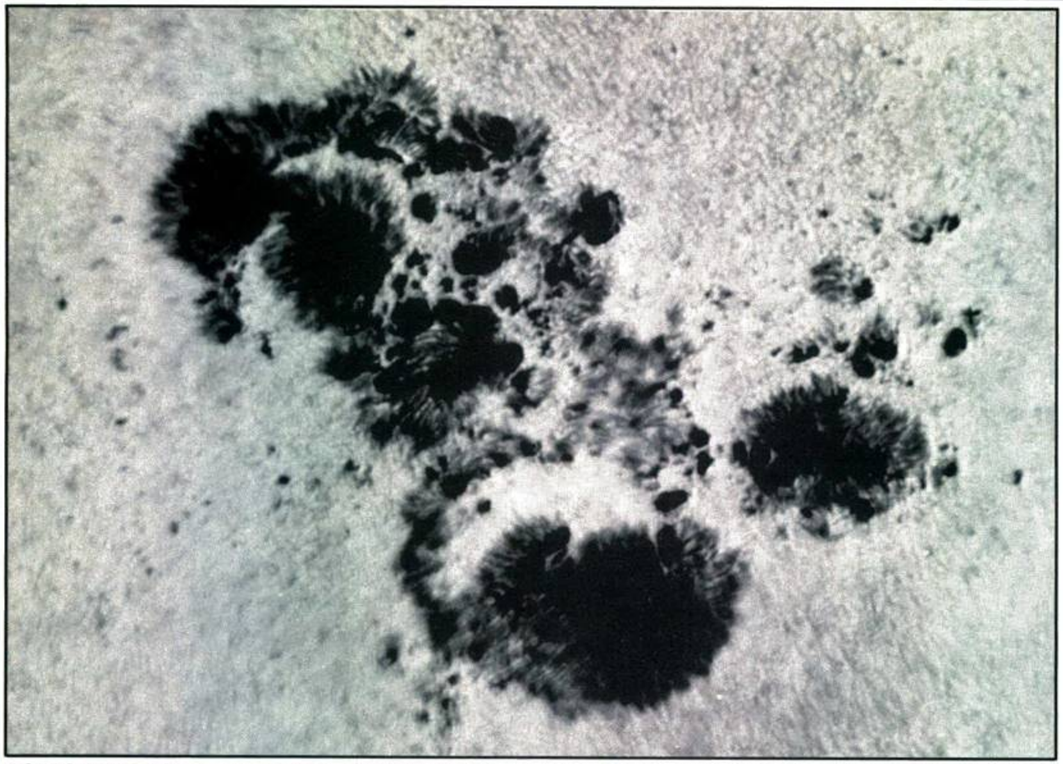

Another incredible photo by Wolfgang Lille of W. Germany. Print resolution is sub-arc second. Unsharp zones are due to heavy turbulence. Photographed July 4, 1988.

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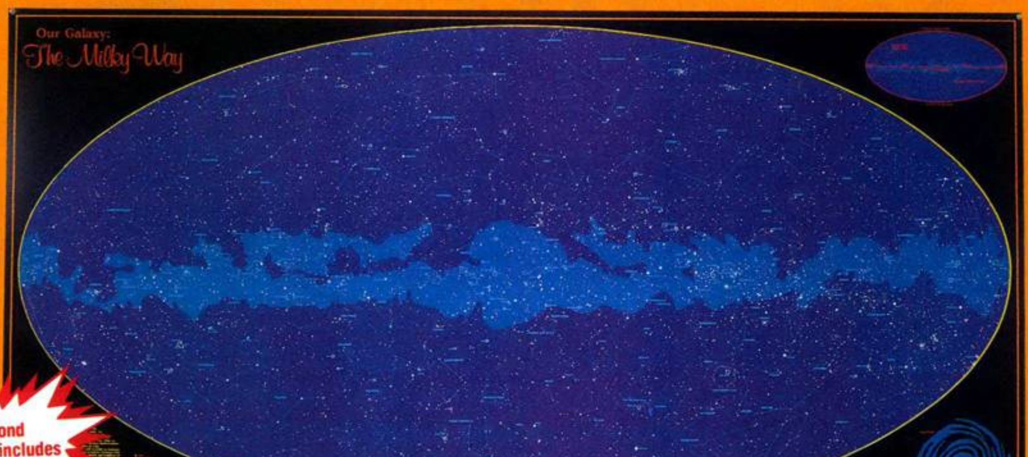

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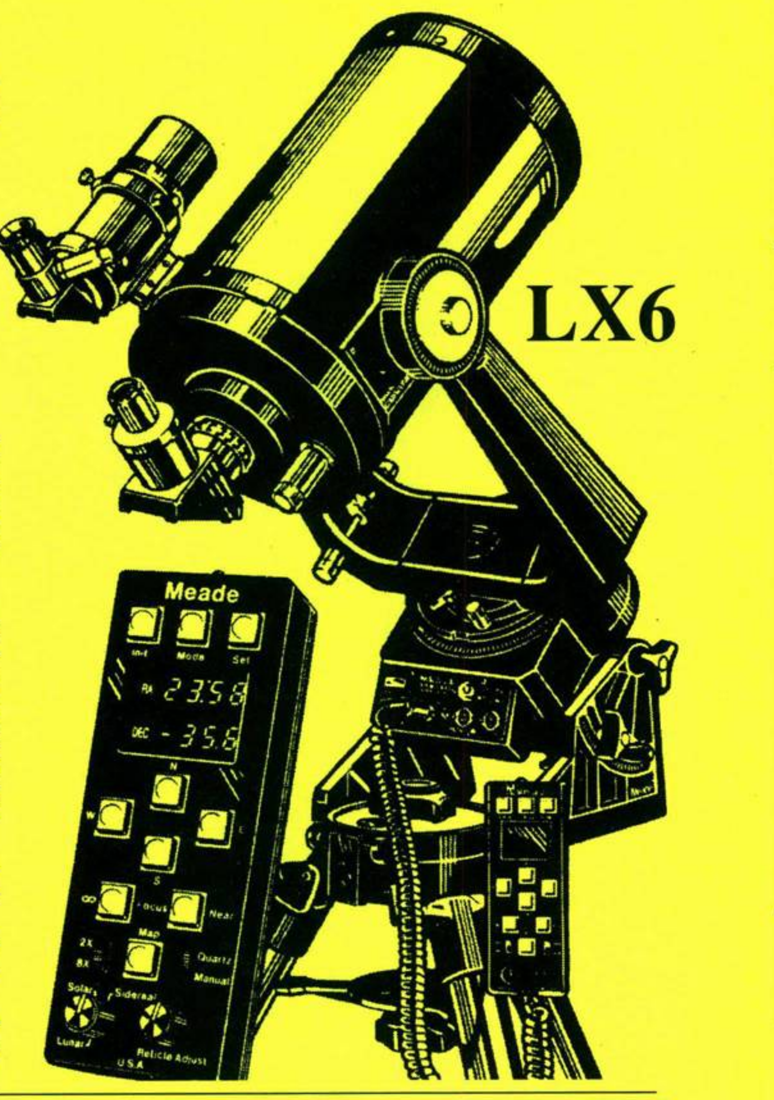

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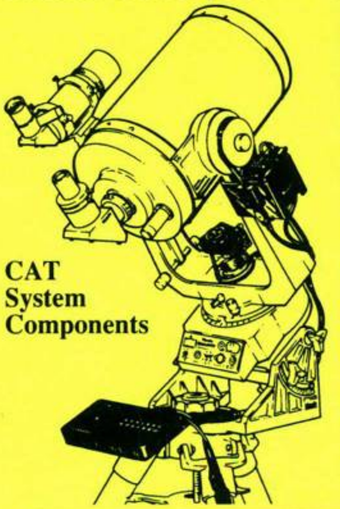
Meade's Computer-Aided Telescope System


CAT System Components

Meade's Computer-Aided Telescope (the "CAT") system has most of the advantages of a computer-controlled telescope at only a fraction of the cost. Consisting of a specially-designed, high-speed, extremely powerful computer, along with a pair of high-resolution incremental shaft encoders and their associated mounting hardware, drive components and cabling (*see general arrangement drawing at left, and panel layout drawing at right*), the CAT can readily and quickly direct you to any of the thousands of celestial objects whose coordinates and other descriptive information are permanently stored in its 1Mb plug-in EPROM database, ***including all of the planets***, as well as to any other celestial object of known coordinates (comets, asteroids, quasars, super-novae, etc.). The computer is loaded with extra features and functionality as the panel legends, at right, indicate.

For the computer-literate, there is also a version of the CAT available with an RS-232C port (the "CAT-COM") for connection to a "PC" compatible personal computer. CAT-COM includes four "demonstration" software subroutines, written in BASIC, to show you how to address and control the CAT from your own computer, as well as the necessary RS-232C interconnect cable. The software is supplied on a 5.25" 360Kby diskette, with backup source-code listings in the instruction manual.

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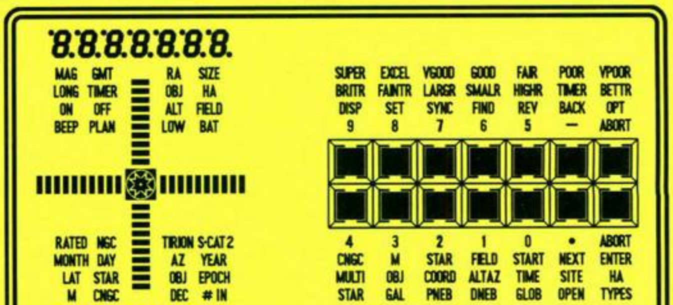
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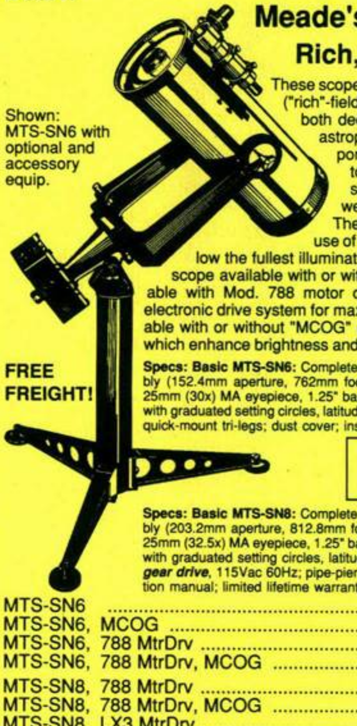

Shown: MTS-SN6 with optional and accessory equip.

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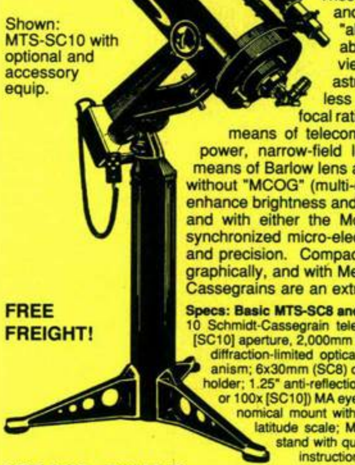

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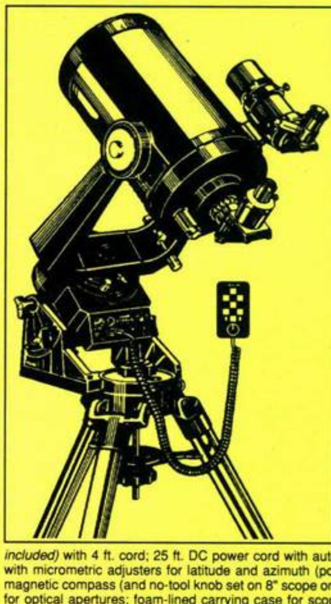

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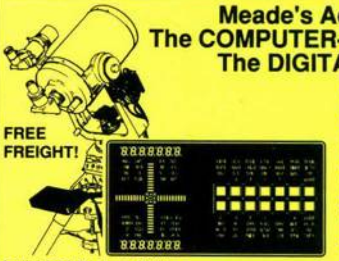

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Astronomy

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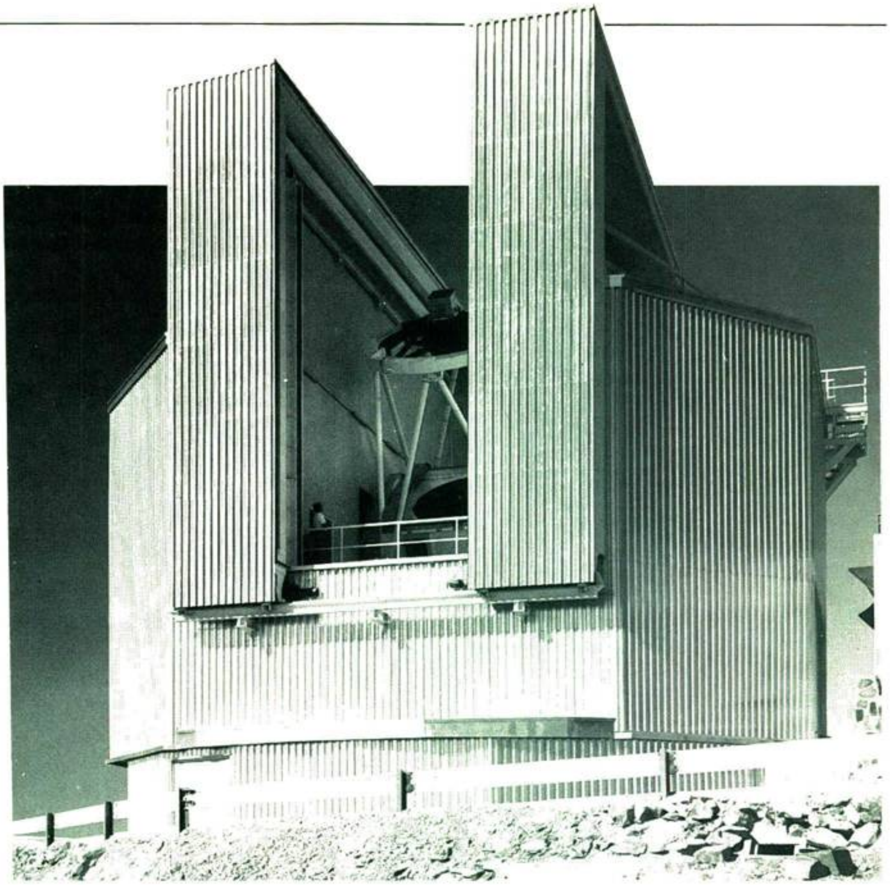
Why don't we see more of them? According to current theory, both the recycled pulsars and the x-ray sources may live for a billion years or more. If these systems are being born at a steady rate, Narayan said, then at any time there should be roughly equal numbers of x-ray sources and recycled pulsars. Instead, according to Narayan's calculations, there are a hundred times more pulsars than x-ray sources in globular clusters.

This discrepancy might be explained if only a small number of recycled pulsars evolve from bright x-ray sources and the remainder are made some other way. Narayan, however, opts for a less extreme possibility: the lifetimes of the x-ray sources that give way to recycled pulsars are one one-hundredth as long as currently believed.

"If we could convince ourselves that the x-ray sources that make recycled pulsars live for only 10 million years rather than a billion years, then there would be no problem," said Narayan. "This is not so unreasonable. Interacting binary stars are complicated objects, and it would be premature to think that we have thought of all the effects that could influence the evolution of these systems."



REVOLUTIONARY "DOME" DESIGN reduces air turbulence at the European Southern Observatory's 3.5-meter New Technology Telescope on La Silla in Chile.

'FIRST LIGHT' FOR NEW TECHNOLOGY TELESCOPE

The European Southern Observatory's 3.5-meter New Technology Telescope at La Silla, Chile, saw first light on the night of March 22/23, 1989, following a three-month period of optical, mechanical, and electronic tests and adjustments. Because of major technical advances in its design, the NTT gives sharper images than any other ground-based optical telescope.

"The NTT performance fully confirms our predictions," said Ray Wilson, head of the ESO optics team, following the tests. Using a CCD camera at the focus of the NTT, astronomers took exposures of numerous astronomical objects, demonstrating a resolution of 0.36 arcseconds. Later tests confirmed that the telescope concentrates 80 percent of its light within a diameter of 0.26 arcseconds.

"We look forward to a rich harvest of scientific discoveries beyond the horizon of other telescopes now in operation," said Massimo Tarenghi, manager of the NTT project. The NTT's sharp images will allow it to observe fainter and more distant objects than conventional telescopes. Compared to ESO's "old" 3.6-meter telescope completed in 1976, the NTT will give three-times-sharper images. Furthermore, its f/2.2 focal ratio makes it three times as "fast" as its predecessor.

The NTT's major innovations include active control of the figures of the primary and secondary mirrors by means of computer control, thermal control that eliminates all sources of heat in and around the telescope and its unique building, and very high precision in pointing and tracking. Also, the NTT is connected via satellite link to ESO Headquarters in Germany and can be operated remotely by astronomers in Europe.

PLANETARY SCIENTISTS FOCUS ON IMPACT GEOLOGY

Impact, and its geological effects, was a focus for many of the more than seven hundred planetary scientists from the United States and around the world who gathered at NASA's Johnson Space Center in Houston, Texas, in March 1989 for the 20th Lunar and Planetary Science Conference. The meeting was the latest in an annual series that began in 1970 after the first *Apollo* Moon landings. The following are short reports on the highlights.

Any large impact on a planetary body will blast portions of the resulting debris into space. Stephen Finney, Brian Tonks, and Jay Melosh of the University of Arizona computer-modeled what happens to this debris using a hypothetical Earth impact large enough to generate a 100-kilometer crater. They found that within 10 million years after the impact, about 13 percent of the escaped debris crashes back on to Earth or the Moon, 25 percent hits Venus, about 1.5 percent strikes Mars, and the same amount falls into the Sun. The rest goes into solar orbit. Finney, Tonks, and Melosh also discovered that ejected material generally migrates sunward: It is ten times easier for escaped Mars material to go to Earth than *vice versa*. They speculated that this may help explain the fact that scientists have found eight meteorites that probably came from Mars, while only three lunar meteorites are known.

A paper by Paul Thomas, Chris Chyba, and Carl Sagan of Cornell University and Leigh Brookshaw of Yale also focused on impacts. They asked what happens to the organic molecules (carbon compounds mostly) in a comet or an asteroid when the object smashes into a planet. They wondered if this could be a way to "salt" the early Earth with prelife organics from which life may have originated. By computer-modeling various impacts, they discovered that despite the shock and violent release of energy in an impact, between 0.1 percent and 1 percent of the organic molecules in a comet or asteroid will survive without being destroyed.

Meteor Crater in northern Arizona is Earth's best-preserved impact crater, but its age has been hard to pin down. Studies of sediments accumulating in the

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David DeVorkin's revealing history examines the role of the military services (the Army Air Corps, Navy's Lighter than Air Division, etc.) and the National Geographic Society and how the balloon program was transformed by the national experience of World War II. Finally, the book evaluates the scientific contributions of the program, its foreshadowing of the Apollo program, and the complex interplay of science, political patronage, and military participation.

This scientific history is intended for anyone who is interested in the history of the exploration of the earth's atmosphere, in ballooning itself, in American science between the wars, and especially in how and why scientists who studied cosmic rays, meteorology, and solar physics participated in the dawn of the space age.

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bottom of the crater previously led to a widely accepted age of 20,000 to 25,000 years. However, a team of eight scientists from three institutions led by K. Nishiizumi of the University of California, San Diego, reported that the impact actually occurred about 40,000 years ago. They base their conclusion on studies of radioactive isotopes (beryllium-10 and aluminum-26) in crater rocks that have been exposed to cosmic rays penetrating Earth's atmosphere from space. The rocks' exposure to cosmic rays began when the impact excavated them and placed them at the surface. From the changes in the isotopes measured today, the scientists could tell how many years have passed since the rocks were unearthed by the impact.

In other work reported at the conference, scientists asked themselves if Mars had an atmosphere of carbon dioxide thick enough to allow running water at its surface ages ago, then where did this CO_2 atmosphere disappear to? A team of seven scientists led by Ted Roush of NASA's Ames Research Center observed Mars in the infrared with the Kuiper Airborne Observatory. Choosing wavelengths sensitive to the presence of weathering products such as carbonates, sulfates, and hydrates, the scientists discovered that Martian dust contains materials that can permanently lock up substantial amounts of carbon dioxide, sulfur dioxide, and water in their chemical structure. They note that the dust provides a handy way to store volatiles that Mars is thought to have outgassed early in its history. "If these chemical 'reservoirs' removed an early thick atmosphere on Mars," they noted, "then we are now seeing our first direct evidence of a warmer period, complete with liquid water."

Planetary cartographer Ray Batson of the U.S. Geological Survey in Flagstaff, Arizona, announced that for the first time the USGS has published a report authored entirely by scientists from the Soviet Union. The publication, released this July, covers the northern hemisphere of Venus from the pole down to about 30° north latitude. It includes four polar stereographic maps at 1:15,000,000 scale — a topographic map, a digital mosaic of radar "photos" taken by *Venera 15* and *16*, a shaded relief map showing the landforms, and a geologic map and commentary. The joint publication, shown at the meeting in preliminary form, combines high-resolution Venus data from the Soviets with information from the U.S. *Pioneer Venus* orbital probe and image-processing by the USGS.

Space News

MARS OBSERVER TO AID SOVIETS

If the Soviet Union goes ahead with its plans to launch another mission to Mars in 1994, it can expect a little help from a U.S. spacecraft that will have just completed an intensive study of the planet. NASA recently decided to equip its *Mars Observer*, scheduled for launch in 1992, with an antenna that will pick up transmissions from the Soviet mission's experiments on the Martian surface.

According to *Mars Observer* project manager David D. Evans of the Jet Propulsion Laboratory, NASA is committed to carrying the relay antenna even though the Soviet Union's plans for their 1994 Mars mission are not yet definite.

JPL is working out the details of mounting the antenna and its electronics on *Mars Observer* with the French space agency, the Centre Nationale D'Etudes Spatiales, which is building the antenna. Data from the French balloon-borne experiments, which will sample the Martian soil in several locations, will be sent to a Soviet orbiter and *Mars Observer* before being relayed to Earth.

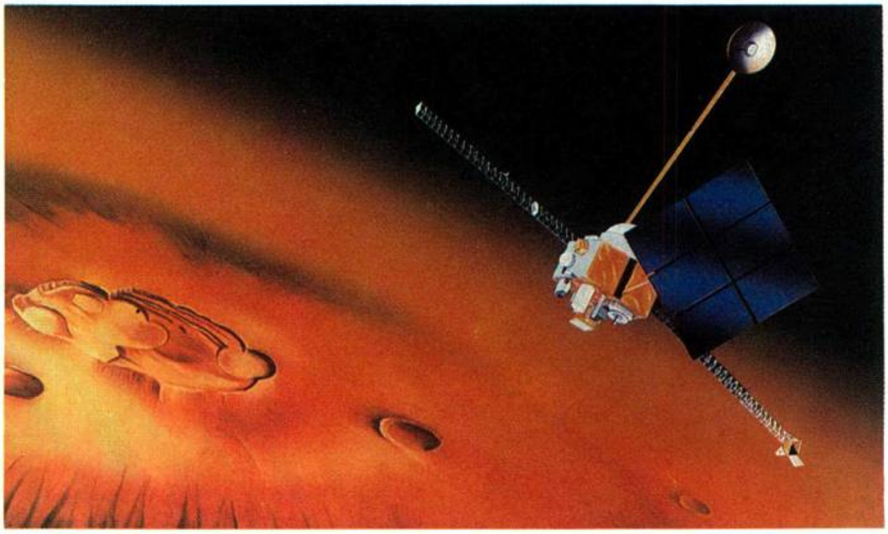
According to current plans, the Soviet spacecraft will arrive at Mars just after *Mars Observer* completes a two-year global mapping cycle in December 1995. For the following three months, *Mars Observer* will turn its attention to relaying balloon data; after that it will return to further observations of Mars.

Project manager Evans has seen no indication that the recent failure of the Soviet *Phobos* mission has caused the Soviets to back away from their ambitious series of Mars missions planned for the late 1990s. (See "The Soviets Advance into the Solar System," July 1988.) "From our limited perspective, we have seen no weakening of their resolve to pursue these missions," said Evans.

The *Mars Observer* mission has just completed its first year of full funding in preparation for launch from a commercial Titan III rocket in September 1992. Construction of the spacecraft gets underway this summer at the General Electric Astro Space Division in Princeton, New Jersey.

The mission has gone through some hard times in the last few years, due in part to the *Challenger* accident. *Mars Observer* was scheduled to be launched in 1990 from the space shuttle but in 1987 NASA decided to delay the mission two years and move it to an expendable launch vehicle.

The delay produced additional expenses that led to a drastic cost-cutting measure: removing one of the mission's scientific instruments. "NASA felt that the mission was becoming unaffordable," said Evans, "so they took a hard look at the entire project and decided the Visual



FROM ITS ORBIT ABOVE MARS, NASA's *Mars Observer* will conduct an intensive two-year study of the planet and then help a Soviet mission relay its data back to Earth.

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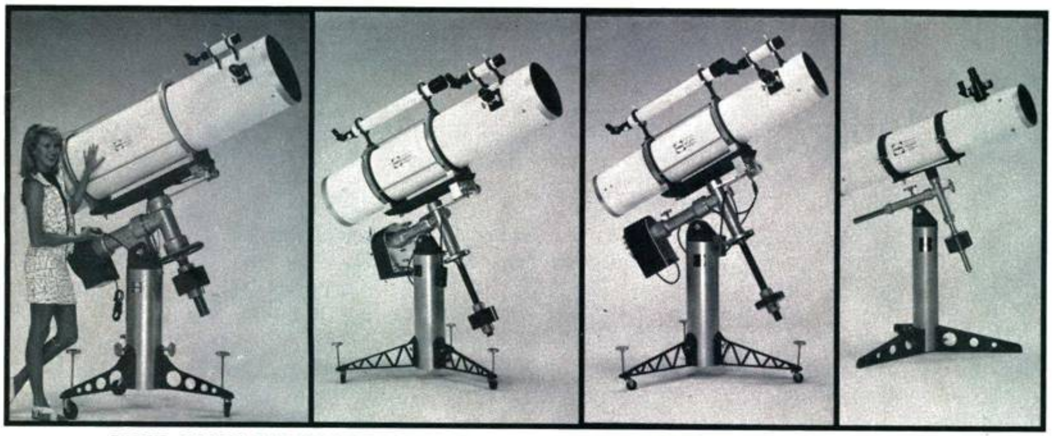

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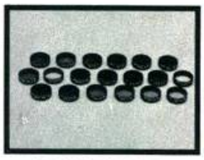

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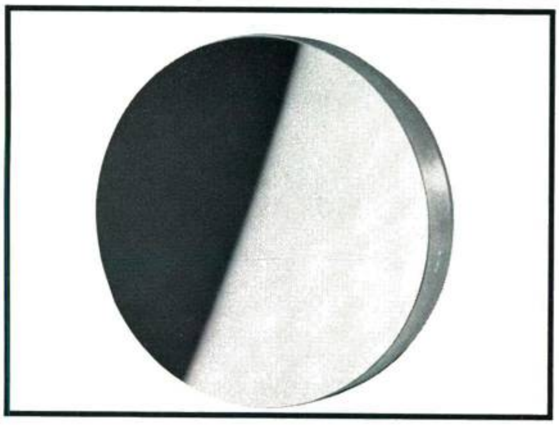

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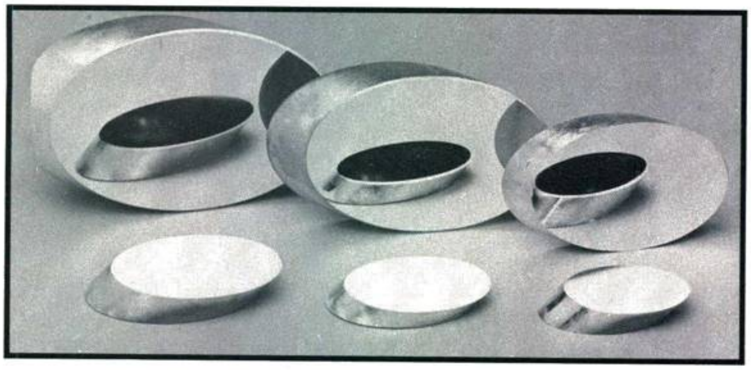

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and Infrared Mapping Spectrometer would be dropped."

The spectrometer may still see service on another mission such as the proposed *Comet Rendezvous/Asteroid Flyby* or the *Cassini* mission to Saturn. It is also being considered by the Soviets for one of their future Mars missions.

GALILEO ON SCHEDULE DESPITE SHUTTLE DELAY

The long-awaited launch of the *Galileo* mission to Jupiter, scheduled for October, will not be jeopardized by the shuttle program's first launch delay since flights resumed last September.

The cause of the delay is the space shuttle *Columbia,* which is to carry a Department of Defense mission on the next shuttle launch. According to Admiral Richard H. Truly, acting NASA administrator, "NASA management has become increasingly concerned that the work involved in preparing *Columbia* for its first flight in over three years is taking long enough that it might endanger the option to launch *Galileo* at the opening of its launch window."

NASA has decided to rearrange the shuttle launch schedule in order to fly *Columbia* late this summer and leave room for the *Galileo* launch on October 12. Two Department of Defense flights were originally scheduled to follow May's *Magellan* mission: the *Columbia* flight (STS-28) on July 1 and *Discovery* (STS-33) on August 10. NASA has bumped STS-33 to the fall, immediately following the *Galileo* launch.

The new schedule, however, will produce delays for future shuttle missions. Although NASA has not yet announced any new launch dates, the rescheduling will postpone the *Hubble Space Telescope* launch, previously planned for December 11, by at least two months.

A one-month delay of *Columbia*'s second mission (STS-32) to retrieve the Long-Duration Exposure Facility (LDEF), originally planned for November, could mean that the spacecraft will fall to Earth before the shuttle arrives. The orbit of LDEF, a 10-ton spacecraft launched in April 1984 carrying a number of experiments, is decaying rapidly, the result of increased atmospheric drag caused by recent high levels of solar activity.

Despite the delays to the rest of the shuttle missions, *Galileo* is proceeding on schedule. The spacecraft arrived at Kennedy Space Center on May 16. It is now completing tests and will be joined to the Jupiter atmospheric probe by the end of July.

Amateur News

BACKYARD OBSERVATORY, TEXAS STYLE

"We're calling it a world-class observatory owned and operated by amateurs," declared W. Barry Smith, an amateur astronomer from Irving, Texas. Smith was talking about his pet project, a computerized 24-inch telescope housed in the newly finished Lone Star Observatory. The structure is located about ninety miles north of Dallas in Atoka, Oklahoma. When completed last spring, the facility became one of the most advanced observatories operated by amateur astronomers in the country.

The idea for the Lone Star Observatory came about six years ago when Smith was vacationing in Egypt's Sahara Desert. During a light show at the Giza Pyramid, the power failed and Smith had his first good look at a truly dark sky. "While sitting out there in the middle of the desert," he said, "I realized I had never seen so many stars in my life. I told my wife that when we got home I was going to buy a telescope."

Enthusiasm turned the telescope into an observatory. Concrete plans for the observatory began two years ago, when Smith attracted several other amateurs in the Dallas area to join in on the venture. Altogether, the twelve partners in the project invested a total of $60,000 and over fifteen hundred hours of work to see the structure to completion.

Smith and the other owners of Lone Star Observatory are pioneering a new system of ownership and management that made completing this project feasible and may occur at other sites in the future. Smith, a broker of business jets, borrowed the philosophy from his company. Smith reasoned that if businessmen pooled together resources to use airplanes, they might do the same for an observatory. Thus, Lone Star is a privately held consortium with a limited ownership of twelve members, each of whom holds a seat on a governing board of directors.

The board votes on observatory policies and each member receives telescope time in blocks of four hours. The distribution of blocks is determined by a lottery conducted at the beginning of each year. As long as members are present at observing sessions, they can bring as many guests as they like.

The observatory has been very popular thus far, largely due to the telescope's size and massive, smooth mounting. The first consideration was large aperture, according to Glen Deen, one of the board members. "The 24-inch was about as large a scope as we could afford," said Deen. The telescope's optics, produced by the Perkin-Elmer Corporation, were engineered by an optical designer who worked on the *Hubble Space Telescope*. The group decided on a massive fork mount similar to one produced for a large scope built by the Orange County Astronomers in California.

The real treat in using the Lone Star Observatory comes with the telescope's computer. Donated by IBM, the aiming software includes voice-activated commands that automatically point the scope to a given point in the sky. Each board member uses a separate chip that recognizes his voice pattern. After plugging in their own chip, Smith and other members can tell the telescope to "find M51" and the scope begins to slew right away. "It's a bit like HAL, the robot from *2001: A Space Odyssey*," says Smith.

ASTRONOMY DAY HANDBOOK AVAILABLE

The second edition of the *Astronomy Day Coordinator's Handbook* has been published by the Astronomical League, the country's largest association of astronomical societies. The 120-page handbook contains practical information and advice for organizers of Astronomy Day gatherings and events.

The first part of the handbook describes the history of Astronomy Day and the many ways it has been celebrated across the United States and Canada. The sections that follow describe display techniques, activities, and methods for sponsoring astronomical societies to obtain new members.

If your astronomy organization is interested in Astronomy Day activities, you can obtain a copy of the handbook by writing on organization letterhead to: Gary Tomlinson, Astronomy Day Handbook, Chaffee Planetarium, 54 Jefferson SE, Grand Rapids, MI 49503. If you have a copy of the first edition, enclose a legal size SASE for an update. If you want a copy of the second edition, send $7 (U.S.); $10 (foreign surface); or $12 (foreign airmail). ☐

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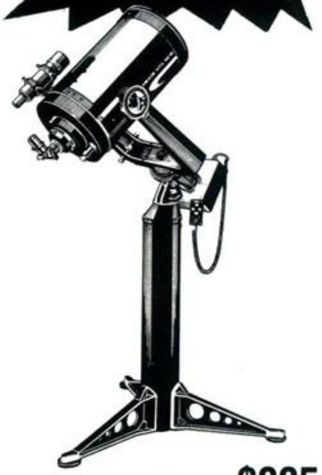

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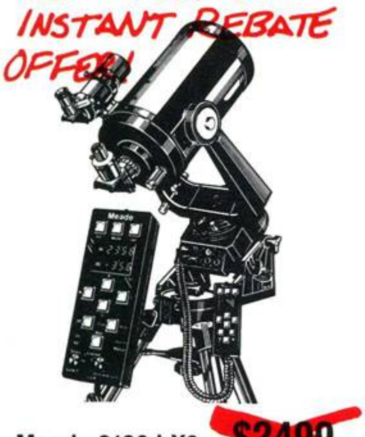

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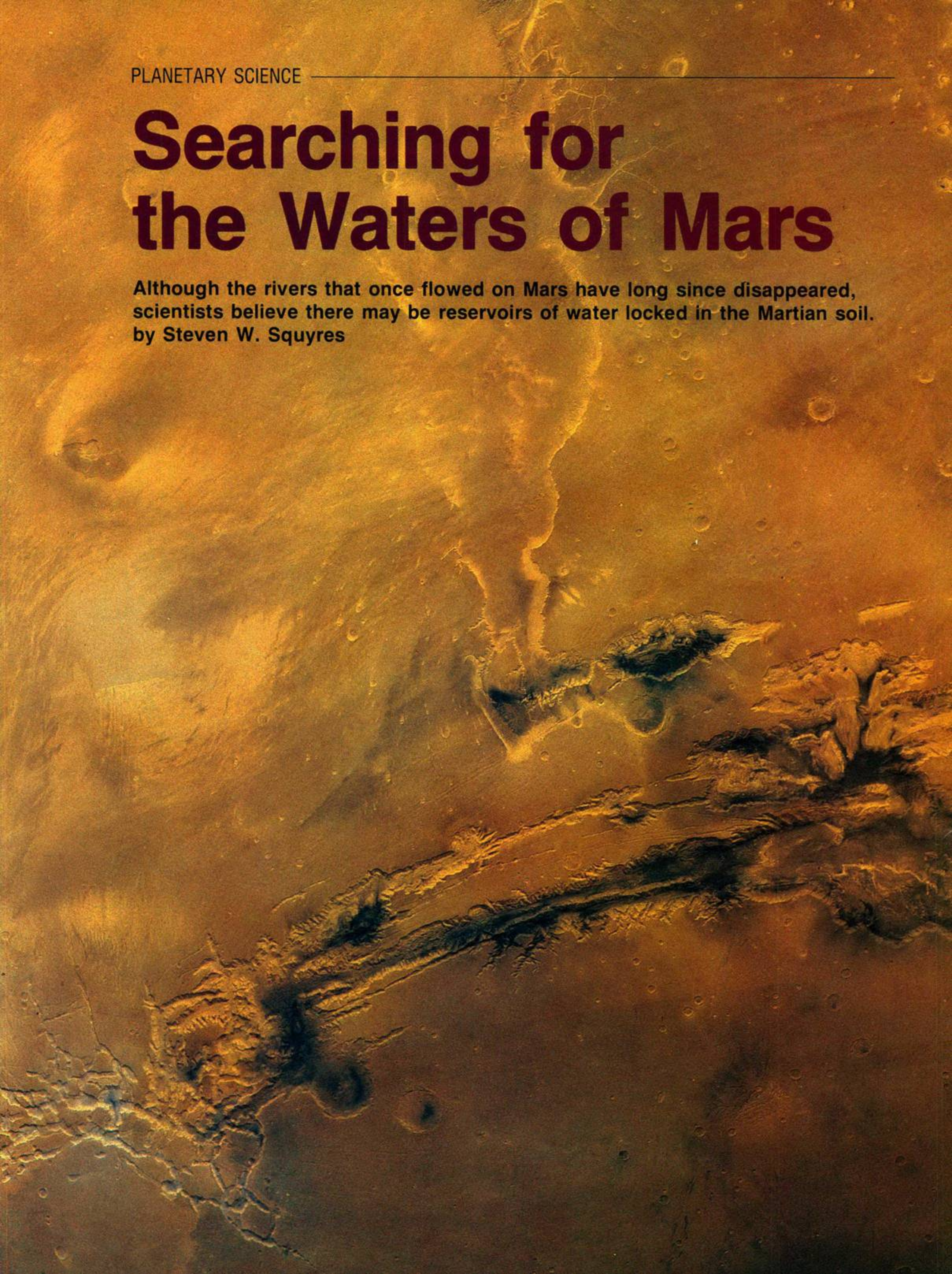
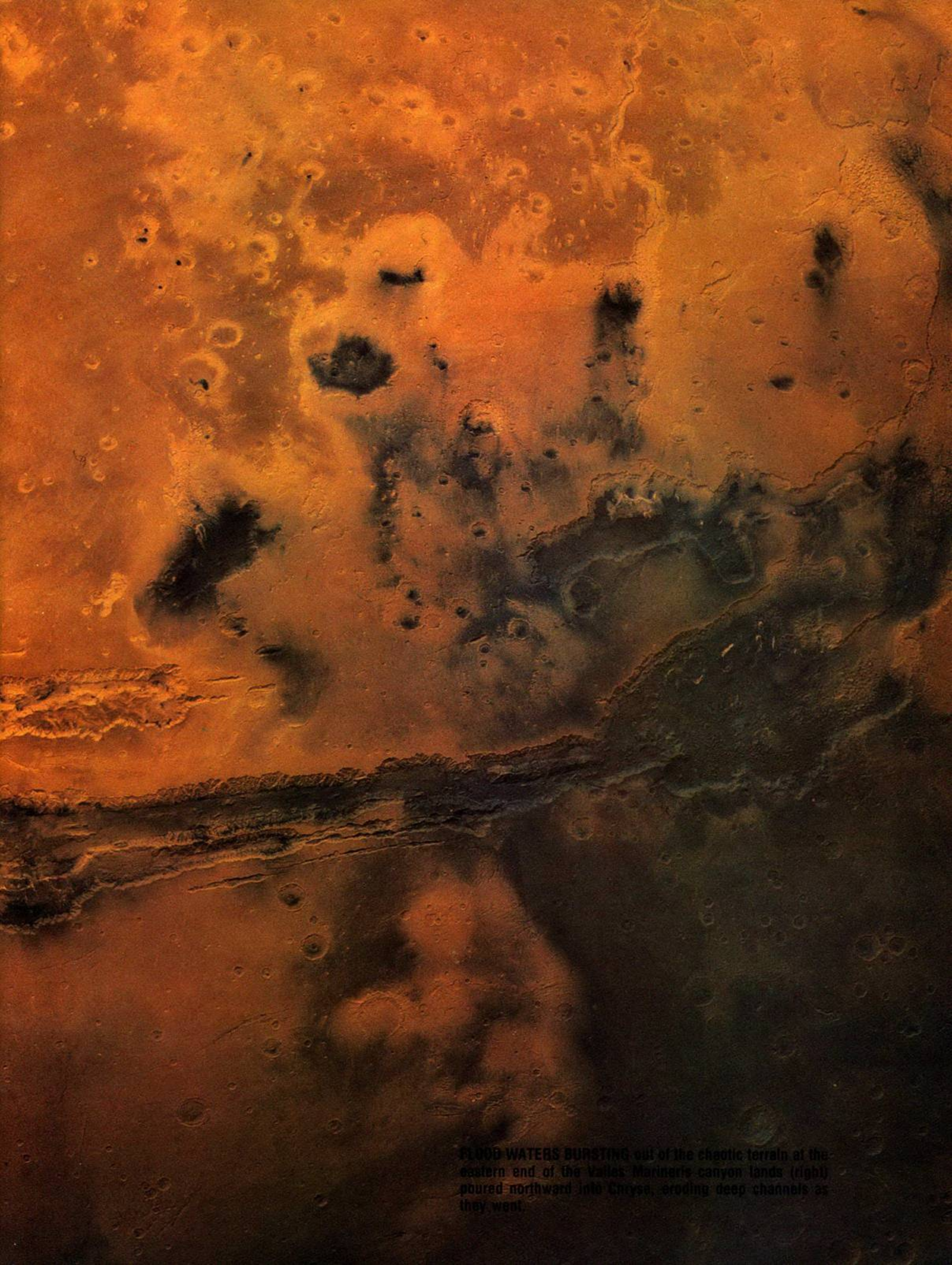
PLANETARY SCIENCE

Searching for the Waters of Mars

Although the rivers that once flowed on Mars have long since disappeared, scientists believe there may be reservoirs of water locked in the Martian soil.

by Steven W. Squyres



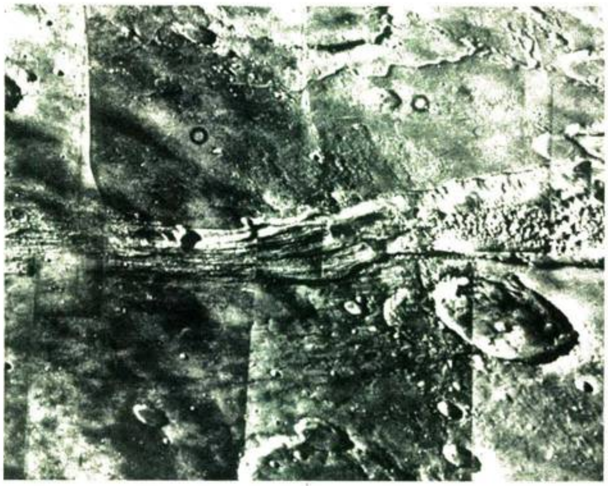


FLOOD WATERS BURSTING out of the chaotic terrain at the eastern end of the Valles Marineris canyon lands (right) poured northward into Chryse, eroding deep channels as they went.

Ever since the *Mariner 9* mission of 1971, everyone has known that today Mars is a planetwide desert, complete with sand dunes and vast rock-strewn wastes. It is also clear that water has played a significant role in Mars' geologic history, though just how important a role has caused much debate among planetary scientists.

Chemical evidence (mainly *Viking* soil and atmosphere analyses) points to only a small amount of Martian water, but even a quick look at certain sections of Mars shows ample *geologic* evidence for the action of water and ice. Recently, as scientists tally up how much water is needed to explain the features on the planet, the Mars that emerges from their calculations is basically a "wet" planet. Moreover, Mars was probably a lot more Earth-like early in its history than it is now.

The task facing anyone who wants to understand Mars is twofold. We need to understand what forces have created its present appearance, and we want to understand what Mars' past climates have been like.



OUTFLOW CHANNELS were carved by catastrophic floods that sprang up from places where the ground collapsed, though the force that released the water is not understood.

One of *Mariner 9*'s most startling and important findings was widespread evidence of Martian water flows. Channels, often remarkably similar to terrestrial stream, river, and flood features, dominate certain areas and are found in many places. Martian channels vary widely but fall into two general categories: outflow channels and valley systems.

Martian Rivers?

Outflow channels are almost unique to Mars. Unlike terrestrial drainage systems, the channels lack tributaries. They literally burst forth from holes in the ground, arising wide, deep, and fully developed in places with complex topographies that indicate the surface has collapsed. The water that carved the channels appears to have gushed from beneath the surface in a flood. Even after flowing great distances, outflow channels bear only a superficial resemblance to terrestrial rivers. Instead, they much more strongly resemble the features formed by catastrophic floods.

In eastern Washington state 14,000 years ago, an enormous ice-plugged lake burst its dam and poured across the countryside in a scouring torrent. At peak, the flood discharged a flow a hundred times greater than the Amazon River. When the flood dissipated, it left behind the Channeled Scablands, an eroded landscape closely resembling Martian outflow channels.

The main difference between the Channeled Scablands and channels on Mars, however, is size. The Martian features are a lot larger — so huge, in fact, that scientists think they could form under the cold climate existing on Mars today. Liquid water freezes rapidly when exposed to the present Martian atmosphere, but the enormous amount of latent heat in such a flood would keep the water flowing along, fizzing and bubbling like dirty, icy seltzer, for many hundreds of miles before it froze. This means that while outflow channels tell us that water has flowed in abundance on Mars, they say little about the ancient climate.

The valley systems on Mars are markedly different from the outflow channels. They superficially resemble terrestrial drainage systems and consist of narrow, often sinuous valleys with branching tributaries. The differences from Earth features, however, are important. Martian tributaries commonly have steep, clifflike walls and rounded, amphitheater-like valley heads. They do not branch the way Earth streams do and show little erosion on the terrain between the valleys. These observations strongly suggest that neither rain nor melted snow carved the valley systems. Instead, their shape is more typical of "sapping," a gradual removal and slow flow of subsurface liquid.

The valley systems are very old. Most lie in the oldest terrain on the planet and show many superimposed impact craters and other indicators of great age. It looks as if Martian valley systems formed only in the earliest part of the planet's geologic history.

Another way valley systems differ from outflow channels is that the water discharges implied by their dimensions are very modest. Eroding by trickles instead of torrents, valley systems formed gradually and probably required a climate less hostile to liquid water than the brawling outflow channels could tolerate.

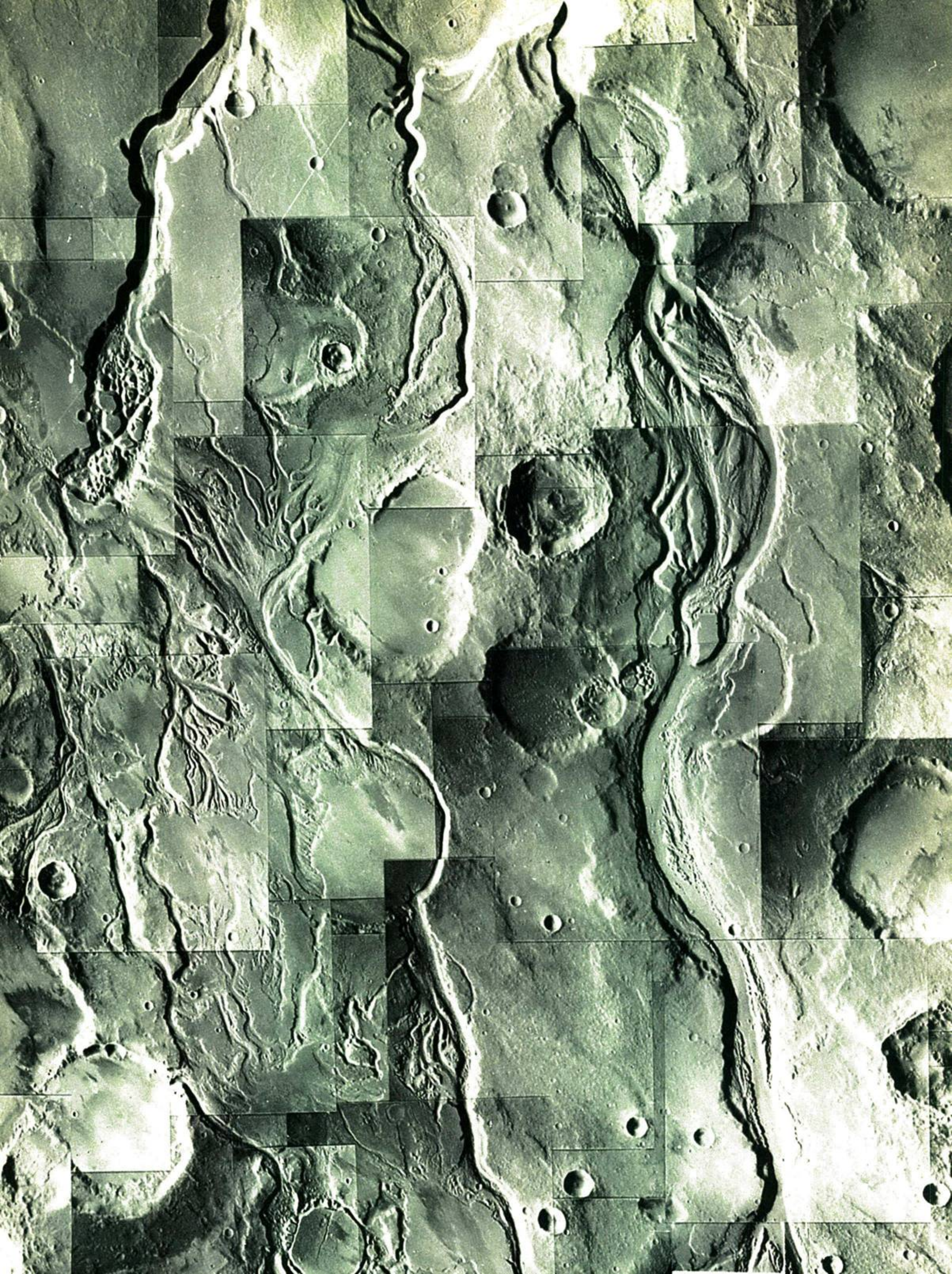
Most planetary geologists think Mars' present climate is too cold and the atmosphere too thin to allow valleys to form today. If this is correct, it means that the early climate of Mars was warmer than today.

A higher temperature in the Martian past could come from the greenhouse effect — the same source that may be warming Earth now. In the case of Mars, the greenhouse would come from an early massive atmosphere composed primarily of carbon dioxide. However, a general lack of valley systems younger than roughly 3.5 billion years hints that a warm epoch, if it did exist, ended quickly.

Tales Told in Ancient Sediments

Channels and valleys are important because erosion is always accompanied by deposition. Whatever nature removes, it delivers someplace else. Moreover, sediments deposited under water can preserve a rich, relatively undisturbed record of the physical, chemical, and biological conditions at the time of deposition.

UNDERGROUND WATER FLOWS "sapped" the terrain at left, creating valleys in eastern Mangala Valles. The crater's ejecta apron shows flow marks that hint at subsurface ice or water.



For instance, most of what we know about Earth's history has been learned by reading the terrestrial sedimentary record. However, our planet's geology has long been active and its early sedimentary record is very fragmentary. Indeed, sediments from the time when Earth possessed its earliest atmosphere — when life was gaining its first footholds — appear to be lacking altogether.

The situation on Mars, thankfully, is very different. Because *Viking* photos show us terrains bisected by streams that dried up ages ago, we know Mars must be fairly rich in ancient water-laid sediments. The outflow channels probably can't tell us much about the ancient Martian environment because channels may date from any era when the climate was like the present. But sediments laid down by trickling streams in the valley systems could show us if Mars once was Earth-like.

Where should we look for Mars' sedimentary record? Valley flow patterns have always been controlled by topography. Mars' ancient terrain contains a lot of closed depressions: impact craters and low spots fenced in by crater walls where sediment-bearing water will collect into ponds. Where a large number of valleys flow into a single, small, well-defined depression, thick beds of sediment should have accumulated because the rocks and soil that eroded from higher up the valleys couldn't go anywhere else.

What conditions might have been present in an early Martian pond? A climate warm enough to permit liquid water exposed directly to the atmosphere may have existed. But it isn't necessary to assume that Mars had a warm climate because substantial stream flow and erosion could take place in a cold climate under a protective ice cover. The most likely place to look for ancient water-laid sediments on Mars, therefore, is wherever a small, shallow, body of water covered with year-round ice could have collected.

Luckily for scientists, perennially ice-covered lakes exist for study here on Earth in the Dry Valleys of Antarctica. Because these lakes are similar to features that may have existed on early Mars, they have been explored intensively. The Dry Valleys' air temperatures range from about −50° Fahrenheit in winter to about 40° F in midsummer, with an annual mean of roughly −5° F. Precipitation is extremely low: a polar desert. Despite the fact that the mean temperature is so cold, the lakes remain liquid under a perpetual ice layer about ten to fifteen feet thick.

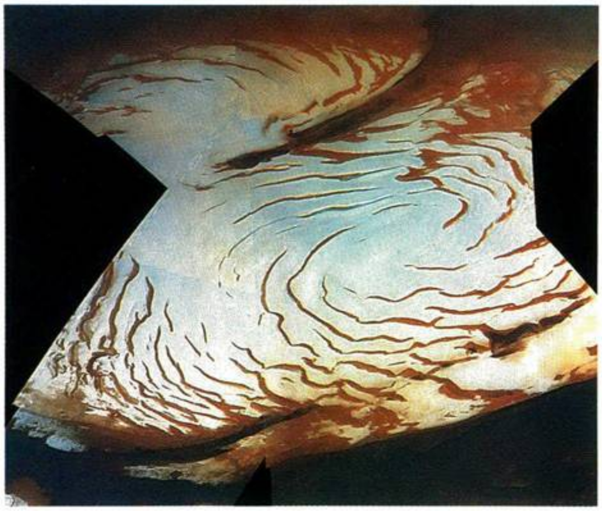
Streams flow into the lakes during summer, but nothing flows out; the only way they lose water is by evaporation from the ice surface. The lakes do not freeze solid because water from inflowing streams or groundwater seepage carries latent heat into them. This heat is released when the lake water freezes at the bottom of the ice cover to form new ice. As long as enough water flows in to balance the loss by evaporation, the lakes will remain liquid, despite very cold temperatures at the surface.

The theoretical description of the heat flow within the Antarctic lakes predicts the actual ice thickness very accurately. Applying this same principle to early lakes on Mars shows that Martian lakes of liquid water could survive under a protective ice cover for long periods of time, even if surface temperatures were several tens of degrees below freezing.

BRAIDED AND TWISTING, outflow channels loosely resemble stream beds on Earth. Scientists think they were carved out quickly as enormous floods gushed across the surface.

Early Martian lakes can also tell us something about chemical conditions on Mars and perhaps help solve a thorny problem. If Mars indeed had an early dense atmosphere of carbon dioxide, scientists are largely stumped to explain where that atmosphere has gone. Only a small amount of carbon dioxide currently exists in the atmosphere and polar caps, and calculations suggest that little has escaped into space. Therefore, scientists have long searched for where Mars may be hiding a substantial amount of carbon dioxide. Carbonate rocks are the most attractive candidate, and lakes supply one ideal environment for them to form.

Dissolved in water, carbon dioxide forms a weak acid that reacts with rock to produce a solution containing carbon, calcium, and magnesium ions. In water these ions can combine to produce calcium and magnesium carbonates, familiar on Earth as limestone and dolomite. Most of Earth's original carbon dioxide now resides in carbonate rocks formed underwater, and the same may be true on Mars.



CANYONS HUNDREDS OF FEET DEEP spiral around Mars' north polar cap, where changes in the Martian climate have interleaved sheets of water ice with layers of wind-borne dust.

If so, then the ancient water-laid sediments of Mars take on doubled significance. They would preserve a record of the climate early in the planet's history. And, if that climate featured a denser carbon dioxide atmosphere, the rocks may actually be the final resting place for some of the carbon dioxide. Thus, paradoxically, an early dense atmosphere would permit liquid water to exist — and the water would promptly remove much of the atmosphere!

The interest in sediments extends beyond the Martian paleoclimate. Most people were disappointed that *Viking* failed to find life. The cold, dry, and highly oxidizing conditions that now prevail on Mars create an environment extremely hostile to life as we know it. However, because Mars and Earth may have been more similar in their early days than they are now, the main

goal in looking for life on Mars has shifted from finding existing life to searching for evidence of former life. And the best place to look may be in the ancient water-laid sediments.

Researchers in both the United States and the Soviet Union are devoting considerable thought to a Mars sample-return mission to bring back surface samples for laboratory analysis. Most mission scenarios involve some kind of roving vehicle to gather samples from a variety of sites. In the Dry Valley lakes on Earth, divers have recovered sediment cores that detail the lakes' conditions over the past several thousand years. The cores include simple microbial mats very similar to the most ancient organisms known to have existed on Earth. If a Mars rover could take similar cores from the dry lake beds, we would learn about the early climate and might even find evidence of extinct Martian life preserved in the sediments.

Water Almost Like Rock

Does Mars have water now? Planetary scientists think so, but they believe that it mostly takes the form of frozen, water-soaked ground. The Martian channels show that the soil, even close to the surface, once had a lot of liquid water, either flowing over or percolating through it. As the temperatures dropped, the water in the ground would freeze and stay in place. However, even if we knew where ice existed immediately after it froze, we couldn't assume that it would be there today because the Martian climate may have removed it.

Locating present-day ice deposits calls for three approaches. The first is calculating where ice can exist using basic thermodynamics. Another is to look for landforms with ice-formed characteristics. The third is to detect ground ice directly with instruments. The first two approaches have been tried and give remarkably similar results. The third will be attempted for the first time on the U.S. *Mars Observer* mission to be launched in 1992.

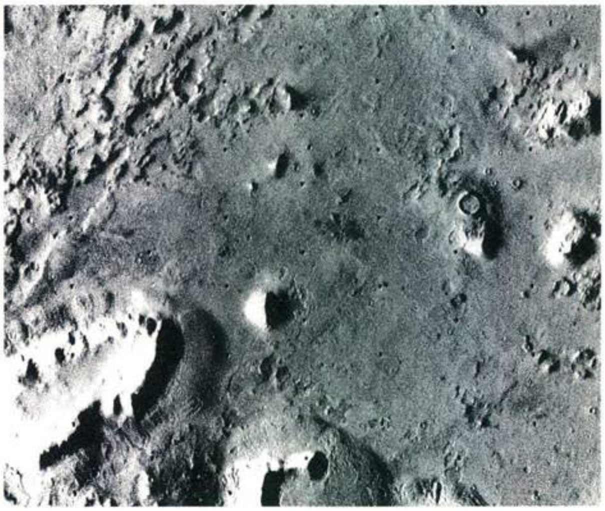
Calculations show that if Martian soil was water-soaked and frozen to a depth of hundreds of feet, the Martian climate, together with heat flowing out from the planet's interior, would inexorably remove some of the ice. If temperatures beneath the surface are warm enough (and "warm enough" can mean roughly −100° F), ice will transform into water vapor and diffuse slowly through the soil, eventually reaching the surface and escaping into the atmosphere. There the water molecules refreeze in colder regions or break apart by ultraviolet radiation and escape to space. The result is that over the lifetime of the planet, all ice in the Martian soil down to hundreds of feet deep completely disappears from the equatorial regions. But ice could persist near the surface at latitudes poleward of 30° to 40° in both northern and southern hemispheres.

This shows where ground ice could exist on Mars, but it can't say where ice does exist. To assess this, let's look at the ways in which ground ice can alter a planet's surface. Ice creeps and flows slowly in a solid state. By geologic standards, it's an extremely mobile material. On Earth, glaciers dramatically demonstrate this by flowing at considerable velocities without melting. Rocky debris cemented by ice is also highly mobile. Space probes have shown that flows of ice and ice-rich materials occur on bodies ranging from Earth to the outer planets' satellites.

WATER ICE AND "DRY" ICE MINGLE in Mars' south polar cap, where temperatures are colder than at the northern cap. A light coating of dry-ice frost blankets the cap year-round.

Two examples of ice flow on Earth are especially relevant. The first is ice-laden permafrost. A vexing problem of construction in the Arctic is the slow creep of ice-rich ground. Even if melting is prevented, the ground can still deform as the ice that cements the soil bends and flows. A second terrestrial example is the rock glacier, found in many Arctic and alpine environments. Rock glaciers consist of loose particles cemented by ice that range in size from boulders to silt. Rock glaciers tend to develop immediately below steep rocky slopes, where they deform and flow without thawing.

Turning now to Mars, photos show a type of flow called terrain softening that is analogous to the ice creep that occurs on Earth. In unsoftened terrain the topography is crisp and rugged: crater rims are sharp, and walls are blocky and angular. Between large craters low but angular ridges and hills exist.



ROCK GLACIERS — mixtures of ice and rock — may have flowed down from these mesas and knobs to form broad, lobe-fronted debris aprons around them.

In the softened terrain, however, crater rims are broad and gentle. Crater walls preserve their blocky nature to some degree, but individual blocks are softly rounded rather than angular. The terrain between large craters has a smooth, rolling character and lacks the angular ridges and hills characteristic of unsoftened terrain. Terrain softening is by no means limited to impact craters alone. It also happens to channels and ridges and other features, where its effects are the same as with craters.

One other feature on Mars that seems to result from a flow of ice-rich material are lobate debris aprons, thick accumulations of rocky fragments at the bases of cliffs. The surface of the debris slopes gently away from the source escarpment and then steepens to form a distinctly bulbous flow front. The shape clearly indicates that the material flowed outward from the escarpment. Debris aprons like those on Mars are probably rock glaciers very much like the ones found on Earth. They are common in some areas of Mars and may contain substantial amounts of ice.

Terrain Softening in Action

To understand terrain softening, scientists turned to a computer technique common in engineering. By simulating the relaxation and flow of a crater formed in icy ground, they found a good match to the Martian landscape with a two-layer model having flow in a thin upper layer only. This calculation tells us that deformation on Mars extends only to shallow depths. Limited deformation seems reasonable based on what is known about the surface: Much of the shallow material has been thoroughly pulverized by cratering. Deeper down, however, this material merges into a fractured but not completely broken-up layer, and deeper still lies intact bedrock.

Therefore, only where the subsurface material is both rich in ice and thoroughly broken up can we expect flows; otherwise, the material will behave like rigid rock. Thus Mars should have deformable, ice-rich soil near the surface that covers unyielding rock below.

ANCIENT SEDIMENTS deposited in depressions where valleys join may provide a look at what Mars' early climate was like. They could also reveal the existence of any now-extinct life.

Mapping where terrain is softened reveals that softening depends strongly on latitude. Virtually no flow features occur within 30° of the equator. In the northern hemisphere, softened terrain exists wherever the ancient cratered highlands extend north of 30° latitude. In the southern hemisphere, cratered highlands dominate, and most regions south of −30° latitude exhibit some degree of terrain softening. The softening occurs everywhere in the middle southern latitudes and becomes less pronounced toward the south pole. The debris aprons — rock glaciers — show a similar distribution.

Comparing this to the calculations of ground-ice longevity, we find that wherever theory predicts ground ice close to the surface, flow features are abundant. On the other hand, wherever the ground becomes warm enough to evaporate the ice, flow features are essentially absent. (The polar regions appear to be an exception to the rule, being rich in ice yet lacking flow features. Flow features are missing at the poles, however, because the ground ice is probably always too cold for extensive flows.) Overall, therefore, we have strong evidence that the shallow Martian soil is rich in ice at high and middle latitudes but depleted of it at low latitudes.

High-Tech Dowsing for Water

Conditions look good for finding ground ice on much of Mars, but proving it's there is another matter. Unless the ice comes within a few feet of the surface, robot spacecraft are going to have difficulty sampling it. One technique, however, can detect shallow Martian ground ice from orbit: gamma-ray spectroscopy. The technique uses the fact that a planet's surface emits gamma rays with energies characteristic of the atomic nuclei present. This offers clues to the elements making up the planet's surface material.

A gamma-ray spectrometer will be part of the payload of the *Mars Observer* mission. Scientists suspect that ice may lie within a foot of the Martian surface at latitudes greater than 50° or 60° in both hemispheres. The gamma-ray technique can "see" about this same distance below the surface and therefore could directly sense the hydrogen in the ice — if the ice is there.

A related technique involving neutrons will double check the gamma-ray results. Hydrogen is among the most effective materials for slowing down neutrons (which is why water is commonly used in nuclear reactors). If significant amounts of hydrogen exist beneath the Martian surface, the neutrons produced by cosmic rays will be very efficiently slowed down. As part of its gamma-ray spectrometer package, *Mars Observer* will carry a kind of neutron spectrometer to determine what fraction of the neutrons leaking out of the surface have been slowed. A portion of the surface where many slow neutrons are observed will indicate ice beneath the surface. By using the gamma-ray and neutron techniques together, it may be possible to map the depth and quantity of ice beneath the surface in the uppermost couple feet of soil.

Mars has come to occupy a special place in the minds of many. Its Earth-like qualities make it special, and foremost among these qualities is the role that water appears to have played in its history.

Water can shape a planet's surface into distinctive and familiar forms and holds clues to the evolution of a planet's climate. Water is probably a prerequisite for the emergence of life, and it will certainly be a necessity for any long-term human habitation.

However, we still don't know enough about Mars. Most of the conclusions written about here are based on conjecture and inference from incomplete data; many may be wrong. We now need further exploration — a comprehensive set of spacecraft missions to map Mars globally, to deploy a network of surface stations, to move about the planet's surface, and to bring samples of Martian materials back to Earth for analysis.

These missions are within mankind's technological reach — all we need is the will to carry them out. They offer the best chance we have to understand Mars and the ways in which it may be like or unlike our own planet. □

Steven W. Squyres is a planetary scientist at Cornell University. His research interests include investigating water on Mars and studying tectonic deformation on the icy satellites in the outer solar system.

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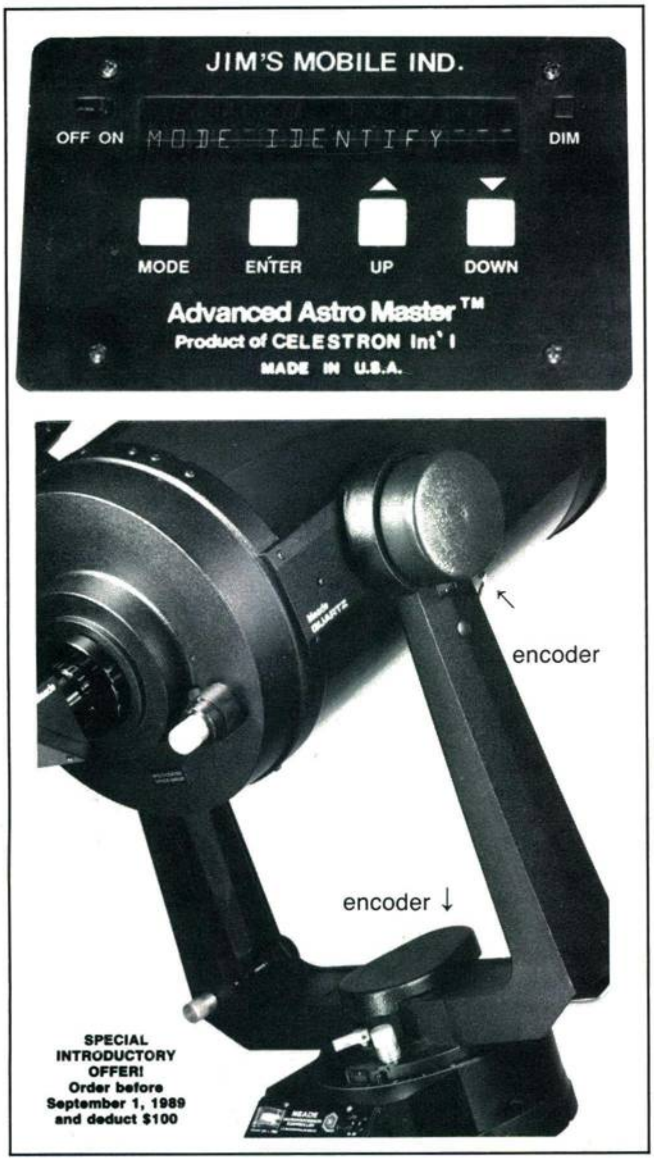

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APPROACHING NEPTUNE

When *Voyager 2* brings us face to face with Neptune on August 25, we will see a planet quite unlike Uranus, with a very dynamic atmosphere.

by Richard Berry

Astronomers once thought of Neptune and Uranus as twins. These big, blue-green planets are nearly alike in size and similar in mass. "Like peas in a pod," astronomers thought, "these gas balls at the chilly fringe of the solar system should be alike."

The first hint that this picture was amiss came in the middle 1970s, when astronomers measured Neptune's infrared radiation.

"Neptune had whopping big infrared emissions," said planetary astronomer Kevin Baines of the Jet Propulsion Laboratory in Pasadena, California. "It was obvious right away that Neptune was different."

When *Voyager* flew past Uranus in 1985, it confirmed what ground-based astronomers already knew: no heat. In fact, the very blandness of Uranus is testimony to a world that, for some reason, seems dead.

In contrast, Neptune is very much alive. Neptune radiates two to three times as much heat energy as it receives from the Sun. Uranus radiates only as much energy as falls on it from the Sun. Neptune clearly draws energy from an internal heat source; Uranus does not.

Today NASA's *Voyager 2* spacecraft races toward an August 25 encounter with the blue-green globe of Neptune. The flyby should establish what astronomers have suspected about Uranus and Neptune for only a decade: cousins they may be, but twins they are not.

Clouds in the Atmosphere

As early as 1948, the French astronomer Bernard Lyot reported features on Neptune; Uranus was featureless. Lyot noted that the extreme remoteness of both planets and their tiny disks made features extremely difficult to see. Because of the difficulty of such observations, the planets were generally ignored.

In the early 1970s, however, Neptune showed itself to be different from Uranus in another way. Whereas Uranus' brightness is rock steady, the brightness of Neptune fluctuates from night to night. This night-to-night fluctuation is especially marked when Neptune is observed with color filters that transmit light that methane absorbs.

Methane, a gas in the atmosphere of both planets, absorbs light in certain red and infrared parts of the spectrum. Because its atmosphere is rich in methane, Neptune reflects little light at these wavelengths and therefore looks blue-green. Moreover, in these red and infrared wavelengths Uranus and Neptune appear dark because methane gas absorbs nearly all the light that strikes them.

When photometry showed that Neptune varies as much as 20 percent in brightness from night to night, astronomers suspected that the variation came from clouds above the methane in the atmosphere that looked bright because the methane did not absorb the light before it was reflected. When Neptune's rotation carried the clouds into view, the planet brightened.

In 1979, Bradford Smith of the University of Arizona, head of the *Voyager* imaging team, used a CCD camera to take pictures of Neptune in the light of a methane absorption band. Although the pictures were fuzzy, they showed bright clouds in both hemispheres. Throughout the early '80s, Smith and other astronomers recorded clouds on Neptune.

When University of Hawaii planetary astronomer Heidi Hammel imaged Neptune in 1986 and 1987 from the peak of Mauna Kea, however, she saw no clouds in the northern hemisphere and one very bright cloud feature in the southern hemisphere at latitude −38°. In 1988, Hammel observed one large bright feature at −30°. Thus Neptune's cloud structure is active and can change significantly in less than a year.

Then in January 1989, eight months before encounter with Neptune, *Voyager*'s cameras recorded a bright feature on the planet at −30°. "It looks like the cloud feature we tracked from Mauna Kea in 1988," said Hammel, now an astronomer at the Jet Propulsion Laboratory. She said the cloud is probably a high, thin cloud. "The very fact that we saw this feature as a bright cloud means that it's above the bulk of methane in Neptune's atmosphere," explained Hammel. "If it were deeper, we wouldn't see it because the methane would absorb the light before it could be reflected back to us."

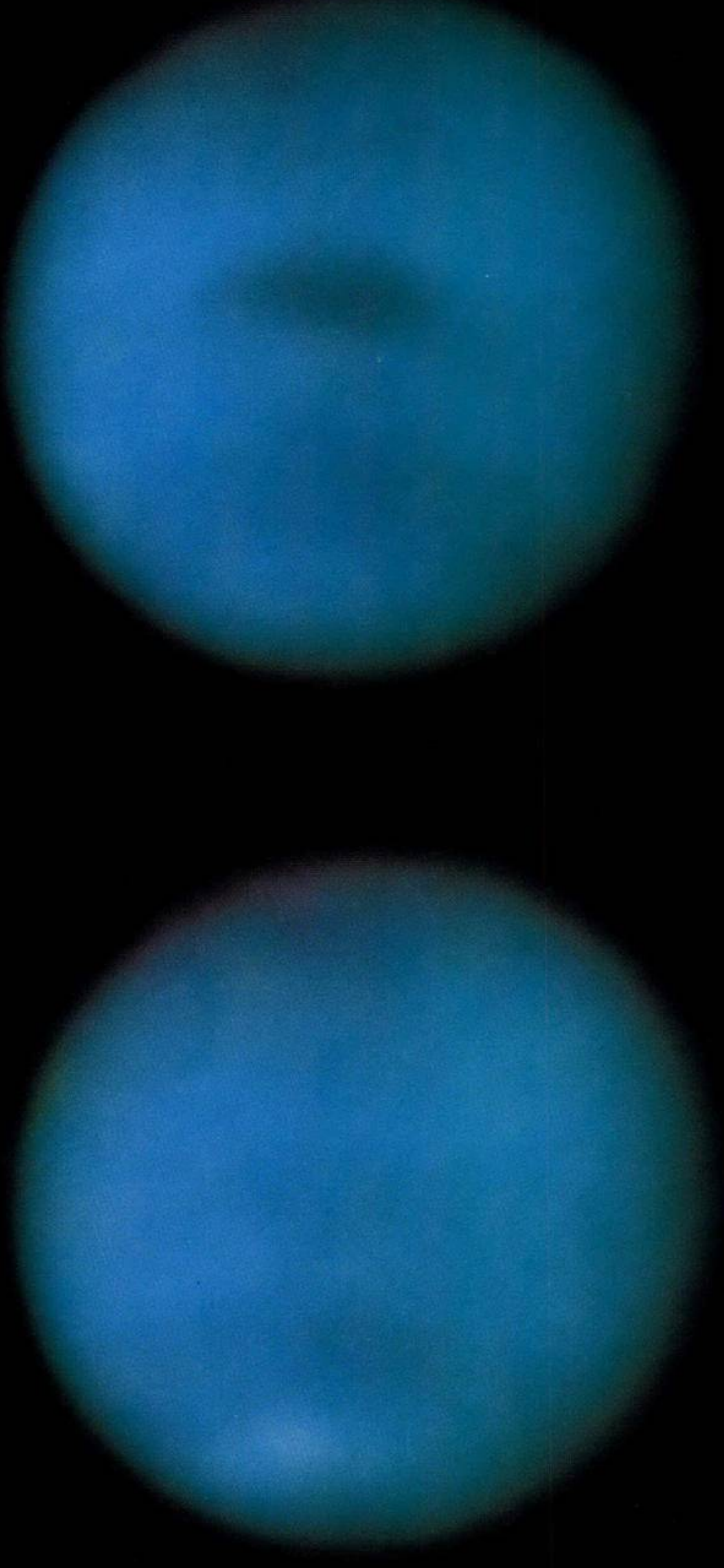
Hammel expects *Voyager* to show Earth-bound humans a lot of structure in Neptune's atmosphere. "It's very encouraging because the *Voyager* pictures are taken with broadband filters rather than methane-band filters. That means that as *Voyager* gets closer, it will show structure without special filters."

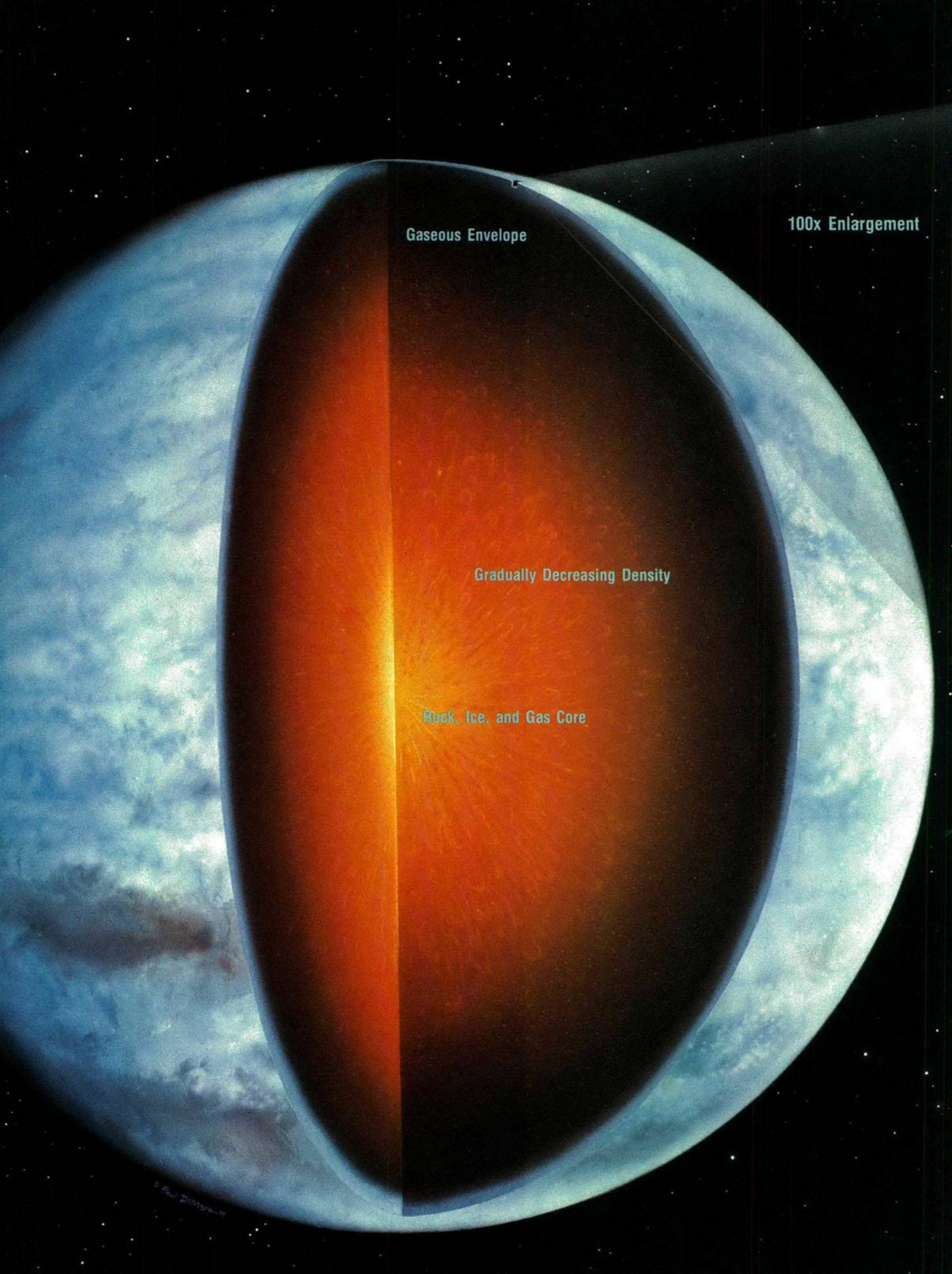
Will *Voyager* show clouds when it reaches Neptune? "We've seen clouds every time we've looked at Neptune. And I've stared at hundreds of images of Neptune in the last three years," Hammel said. "There's a lot of structure visible right at the edge of detection. Little wisps in the northern hemisphere — stuff like that. Nothing to write a paper about."

As *Voyager* showed in 1985, Uranus is virtually featureless. But if Hammel is right, *Voyager*'s cameras will

Voyager Finds Cloud Features on Neptune

Taken 5 hours apart, the latest *Voyager* images reveal dark and bright clouds on Neptune. The top image shows a large dark feature first recorded by *Voyager* some three months earlier. The lower image, made after the planet had rotated roughly 100 degrees, shows a large bright cloud near the south pole. This cloud was only faintly visible in a picture taken 18 hours earlier, suggesting that Neptune has very dynamic weather. (In these pictures, Neptune rotates from left to right.) The large white spot recorded in January (shown on page 34) has faded in contrast. The *Voyager* camera made these images on April 26 from a range of 176 million kilometers through violet, clear, and orange filters, which were combined to produce color pictures.

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Gaseous Envelope
Gradually Decreasing Density
Rock, Ice, and Gas Core
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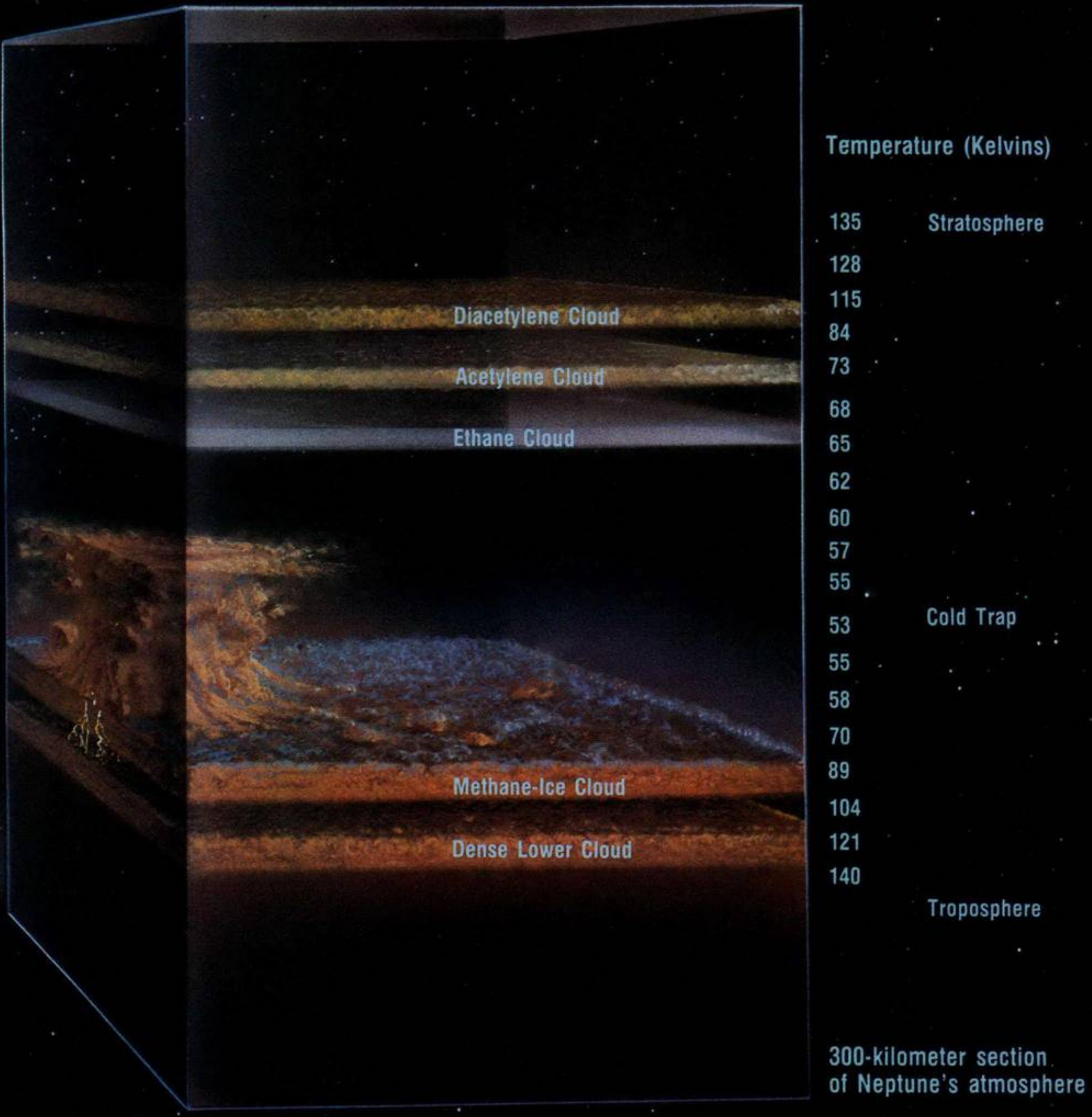
Temperature (Kelvins)
135
Stratosphere
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115
Diacetylene Cloud
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73
Acetylene Cloud
68
Ethane Cloud
65
62
60
57
55
53
Cold Trap
55
58
70
89
Methane-Ice Cloud
104
121
Dense Lower Cloud
140
Troposphere

300-kilometer section
of Neptune's atmosphere

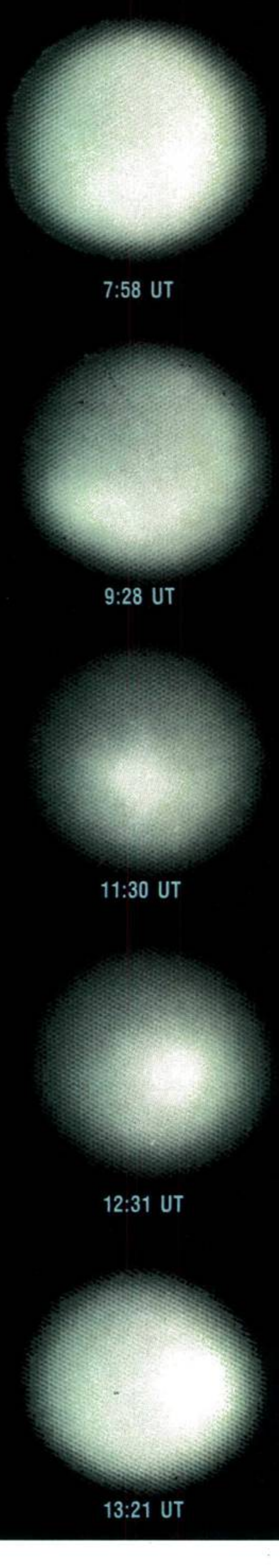
Inside an Icy Giant

Neptune is a vast globe of rock, ice, and gas. At its core the planet is intensely hot — at least 10,000 kelvins — with heat left over from its cataclysmic birth 4.5 billion years ago. In addition, the core is squeezed by millions of atmospheres of pressure from the immense weight of the planet. In this environment, ice invades the atomic structure of rock, rock dissolves in ice, and gas penetrates both ice and rock freely.

Heat escaping from the core makes Neptune active. Deep inside, vast currents of hot material rise and carry heat to warm the gaseous envelope from below. That heat then drives powerful planetary winds and huge storms lofting methane high into Neptune's stratosphere, where the methane interacts with sunlight to form clouds. When the heat escapes into space, astronomers use it to learn about the planet's interior.

Neptune: From Earth and from *Voyager*

From the surface of Earth, our atmosphere makes even the very best images of Neptune soft and fuzzy. In the photographs at right taken July 14, 1988, through an orange methane-band filter, a bright feature moves from left to right across the disk of Neptune as the planet rotates. Numbers show the times at which the pictures were taken.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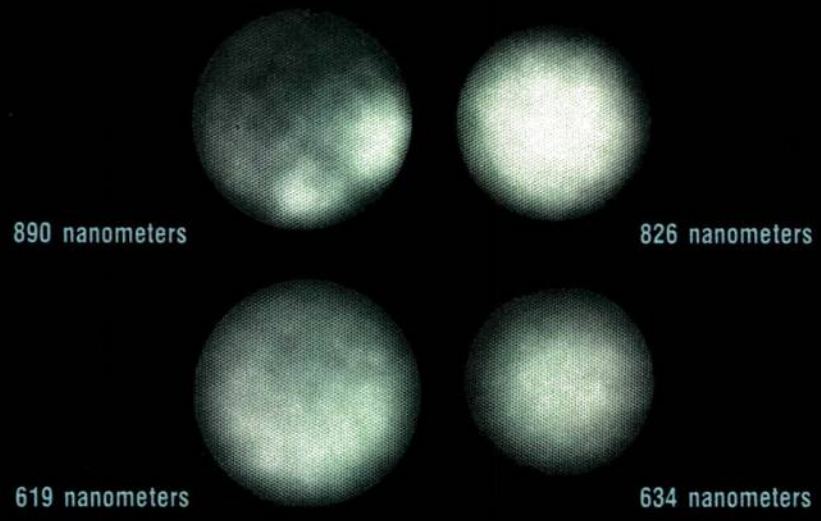

890 nanometers

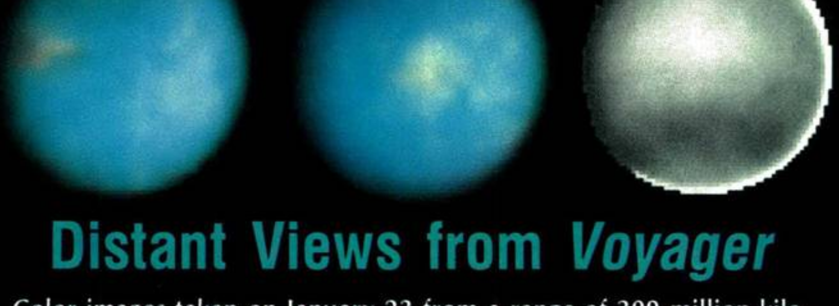
826 nanometers

619 nanometers

634 nanometers

Different at Different Wavelengths

From crude images like these, atmospheric scientists have deduced the overall structure of Neptune's atmosphere. Neptune's appearance depends strongly on the color of the light in which we view it. Pictures taken in light that methane absorbs (left-hand pair) reveal high-level cloud features, whereas pictures taken in light that methane does not absorb (right-hand pair) reveal a dark planetary limb.



Distant Views from *Voyager*

Color images taken on January 23 from a range of 309 million kilometers show a large, light-colored cloud crossing the disk of Neptune as the planet rotates. A black-and-white image shows parallel east-west bands in the atmosphere, much like the cloud belts of Jupiter and Saturn. *Voyager* will take images during the flyby with 500 times better resolution.

depict Neptune's clouds in exquisite detail.

Neptune's Dynamic Methane

Hammel's high-altitude clouds pose a problem for atmospheric modelers like Kevin Baines, Sushil Atreya, and Paul Romani. Something has to make those clouds, and the logical choice is methane. But how did it get there? The atmospheric temperature drops to a minimum of 53 kelvins in the troposphere, a "trap" that is cold enough to freeze and trap every gas except hydrogen and helium in the lower atmosphere. Methane freezes far below the level where Hammel sees it, forming deep clouds of methane ice crystals.

To further confound astronomers, spectroscopy shows that the methane escaping into the upper atmosphere of Neptune is no small leak. Three percent of the molecules in Neptune's upper atmosphere are methane molecules, while in the stratosphere of Uranus only one molecule in a hundred thousand is methane.

The high concentration of methane in Neptune's stratosphere is an observational fact that any model of the atmosphere must explain, and an important way in which Neptune and Uranus are different. Why does Uranus trap its methane gas in the lower atmosphere if Neptune doesn't? How can Neptune's methane get through the cold trap?

"Neptune is so dynamic," claimed Baines, "the planet has to be driven by the internal heat source." The strong outflow of heat creates instabilities in the atmosphere. Gas heated from below rises, dumps its energy, and descends. Yet this process — convection — is ordinarily not enough to carry methane up at least 60 kilometers, as is the case in Neptune's upper atmosphere.

On Earth, convection sometimes creates large storms, but even the largest ones raise ground-level air only 15 kilometers. One model for Neptunian storms, the convective overshoot hypothesis, postulates that when a mass of methane-laden hydrogen begins to rise, it becomes unstable and rises more rapidly. Some of the methane condenses and its latent heat warms the surrounding air. The parcel of air thus gains even more buoyancy and shoots upward. The process feeds on itself, and the rising plume of the storm "punches through" the tropospheric cold trap, depositing methane ice crystals high in the stratosphere.

Once methane is above the cold trap, it evaporates because the stratosphere is warmed by sunlight. But even when methane has been lofted into Neptune's stratosphere, it does not remain there long. Methane absorbs sunlight and becomes hot. Solar ultraviolet light then disassociates the warm methane molecules, that is, knocks off one or more hydrogen atoms.

The highly reactive molecular fragments reunite to form molecules of ethane, acetylene, diacetylene, and heavier hydrocarbons that condense into tiny droplets. High, thin clouds made of these aerosols are probably what Hammel's ground-based pictures of Neptune show. But the droplets in the clouds soon form bigger drops and fall toward the lower atmosphere. Within a year this process would remove most of the hydrocarbon aerosols in the stratosphere, if the aerosols and the methane that makes them were not continuously replenished.

"Uranus is sort of a dead planet," observed Baines. "Most of the methane freezes out, so there are few clouds in the upper atmosphere." Neptune is different. "It would be exciting to see one of these big updrafts punching out on Neptune," said Baines, "but we don't know if that's happening, and we won't know until we get there and see what's going on."

Why Are They So Different?

In mass and size Neptune and Uranus might be mistaken for twins — and yet they aren't twins. Neptune is cloud-spotted and Uranus is bland. Neptune radiates heat from deep inside, while Uranus is warmed by feeble sunlight. How did they come to be so different?

That's a question with which planetary physicist David Stevenson of the California Institute of Technology has wrestled. "The basic answer," he said, "lies in how well the constituents of the two planets are mixed and how that mixing came about through the process of planetary formation."

Both planets are made of the same basic mix of rock, ice, and gas, said Stevenson, though slightly denser Neptune may have a bit more rock and somewhat less gas. In Neptune these materials are mixed well, while in Uranus they are not. "Uranus has a bottom-heavy interior that inhibits convection," explained Stevenson.

At the high temperatures and pressures in the core of a planet — 10,000 kelvins and several million atmospheres of pressure — rock, ice, and gas intermix freely. Both Uranus and Neptune are richest in rocky material in the innermost core, but even the core probably contains ice and gas. In Uranus, however, there is a higher fraction of rock deep down, which makes the interior of Uranus bottom-heavy.

The bottom-heavy core traps heat inside Uranus. If warm core material moves up, it finds itself surrounded by material intrinsically lighter than it is, so it sinks back. "The composition gradient makes Uranus stable, so convection is turned off, and the primordial heat is bottled up inside," said Stevenson. Inside better-mixed Neptune, convection moves heat out of the core and toward the surface.

Armed with an accurate measurement of Neptune's rotation period, investigators will disentangle the distribution of mass inside the planet from the planet's oblateness, which is caused by rotation. "We'll be able to give an educated guess about the composition gradients when we have good measurements of the gravitational field," said Stevenson. *Voyager* will probe Neptune's gravitational field and will thus provide raw data for planetary-interior modelers.

The difference between Uranus and Neptune, stressed Stevenson, may stem from chance events late in their formation. Neptune's last big impactor hit head-on, heating and mixing the planet's interior, which resulted in an interior that convects so heat bleeds out. The last major object to strike Uranus landed a glancing blow and set the planet spinning sideways, but it did not mix the interior. Uranus thus remained stratified, and heat does not escape.

Uranus' impactor may also explain its satellite system. In this scenario, satellites condensed from material splashed out of Uranus by the last big impacting body. "It fits together rather nicely," said Stevenson, "because with one oblique impact you can explain the tip of Uranus' rotational axis, its lack of heat flow, its interior structure, and its satellite system."

Neptune, on the other hand, captured its large satellite Triton, which travels in an inclined and retrograde (backward) orbit. "Triton may be the type of object that Neptune accumulated from," said Stevenson. "Once we know the composition of Triton, the next question is,

Cousins, but Not Twins

	Neptune	Uranus
Mass (kilograms)	$102\text{x}10^{24}$	$87\text{x}10^{24}$
Radius (kilometers)	24,300	25,000
Density (g/cm^3)	1.7	1.3
Heat Flow (times solar input)	2.5	1
Methane (parts per million in the stratosphere)	30,000	10
Axial Tilt (degrees)	29	98
Rotation (hours)	17.7(?)	17.2

could you make a Neptune from an accumulation of Tritons plus a dash of gas?"

Instruments Probe a Planet

Voyager will not penetrate Neptune's core, but it will fly past with its payload of scientific instruments. From a range of thousands of kilometers, the instruments will sense many kinds of radiation and measure many forces, seeking clues that scientists will use to construct a model of the interior.

Each instrument takes a specific type of data, but data from the instruments can be used for many purposes. For example, the four *Voyager* magnetometers measure the strength and direction of the magnetic field. Because the magnetic field arises inside the planet, its strength, orientation, and shape offer clues about the interior. Neptune's magnetic field may be complex and, according to Stevenson, generated well outside the planet's core in the electrically conductive "soup" three-fourths of the way to the surface. *Voyager* will test these conjectures, to replace guesswork with data.

Voyager's infrared radiometer measures the excess heat radiated into space and thus the strength of Neptune's internal heat source. This instrument will scan Neptune's disk again and again during its incoming and outgoing trajectories to map the outflow of heat on the day and night sides of the planet.

The ultraviolet spectrometer observes how the atmosphere reflects and scatters ultraviolet light. Hydrogen, helium, methane, and hydrocarbons interact with ultraviolet light, making this instrument a powerful tool for analyzing the composition, temperature, and structure of Neptune's atmosphere. In one dramatic experiment planned shortly after closest approach, when *Voyager* flies behind Neptune, the ultraviolet spectrometer will observe the spectrum of the Sun as it shines through and around the planet, probing deep into the lower layers. The result will be a structural profile of the atmosphere, cutting deep into regions where no spacecraft could go.

The *Voyager* cameras, of course, will answer countless scientific questions about the size and distribution of Neptune's clouds and whether powerful winds blow around the equator as astronomers expect. The cameras also will possibly sight the storms that astronomers suspect loft methane into Neptune's stratosphere and reveal high-level hazes in the atmosphere on the limb of Neptune, where edge-on they are easy to see.

Lastly, *Voyager* itself will probe the gravitational field of Neptune. Radio signals from the spacecraft tell with high precision where it is and how fast it is travelling — and from that information, scientists will derive the distribution of mass inside the big green planet.

The Solar System Is the Prize

When *Voyager* flies past Neptune, we will have seen all the major planetary bodies in the solar system up close. (Many small bodies will remain unexplored, of course, including Pluto, thousands of asteroids, and millions of comets.) At stake in the Neptune flyby is a grand synthesis of the history of the solar system.

From a vast, disk-shaped cloud of gas, astronomers believe, fine grains of materials condensed as the disk cooled. Near the Sun, where the nebula was still quite warm, metals, metal oxides, and silicate materials condensed, and grains grew into rocky bodies. In the cooler parts of the nebula far from the Sun, vast amounts of water, methane, and ammonia vapor condensed into grains of ice.

At the outer fringes of the solar system, icy materials constituted the bulk of the planet-forming material, so large planets formed. Uranus and Neptune grew from the accumulation of thousands of planetoids, and they grew so large that they drew some of the uncondensed gases of the nebula — hydrogen and helium — into their bulk.

Between the rocky inner worlds and the icy outer worlds, two bodies grew so large that virtually everything in their region, including vast amounts of gas, fell into them. These huge bodies — Jupiter and Saturn — together account for roughly 92 percent of the planetary mass in the solar system.

Although astronomers still call them gas giants, Uranus and Neptune are actually composed of mostly rock and ice. Whereas the true gas giants, Jupiter and Saturn, are composed of 97 and 70 percent, respectively, hydrogen and helium by mass, Uranus and Neptune contain only 10 to 20 percent hydrogen and helium. Because they accumulated from the impacts of bodies containing both ice and rock — comets, tritons, plutos, and ice-earths — they are not true gas giants.

Although they are more like each other than they are like Jupiter and Saturn, Uranus and Neptune are quite different planets. Deep inside their cores both Uranus and Neptune harbor vast stores of primordial heat. In Uranus the heat is trapped in the interior, unable to escape. From Neptune that heat flows out, energizing deep convective currents and great winds, until it escapes to space. Cousins, rather than twins, describes the relationship between these worlds.

So we think.

Voyager 2's flyby on August 25 will test the models scientists have conceived to explain the solar system. It's unlikely that data from a single space probe will solve mysteries of 4.5 billion years standing. But after the flyby we will know a lot more about Neptune than we do now and will be that much closer to answering the questions that the solar system poses. □

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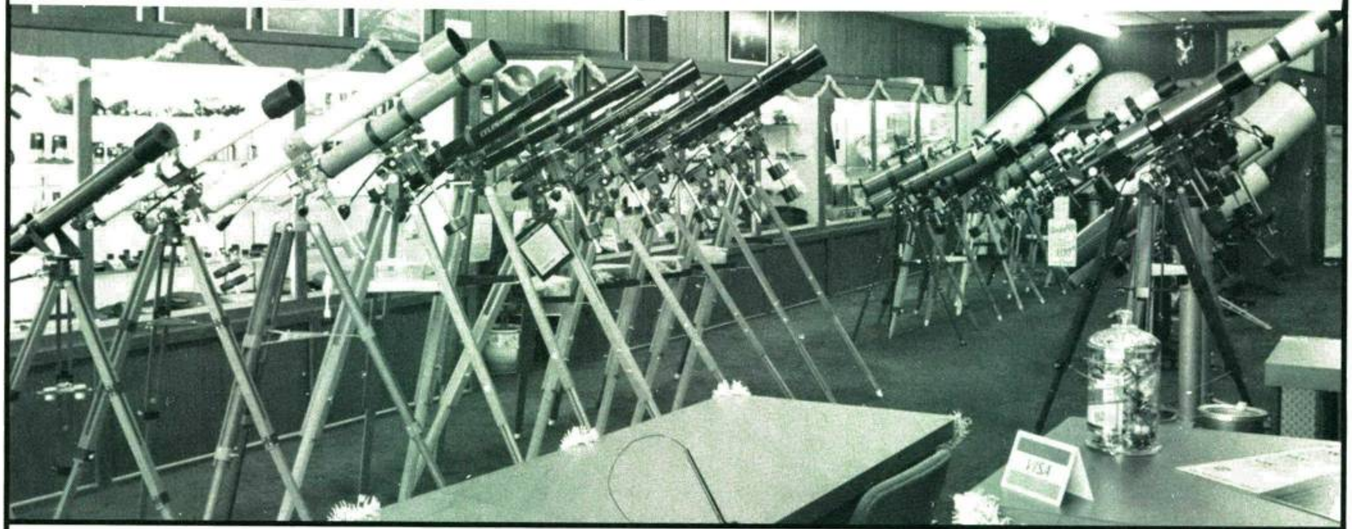

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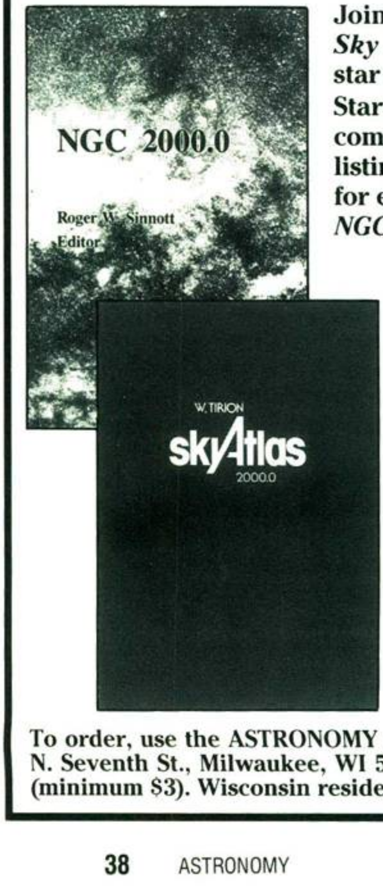

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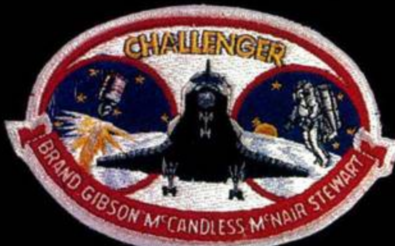
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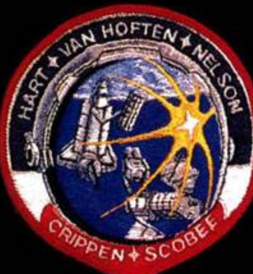
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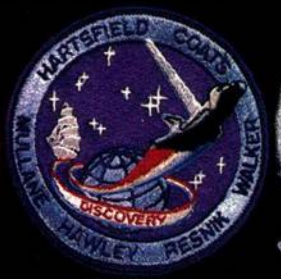
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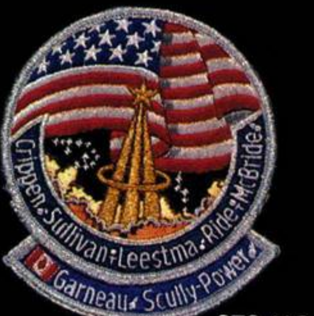
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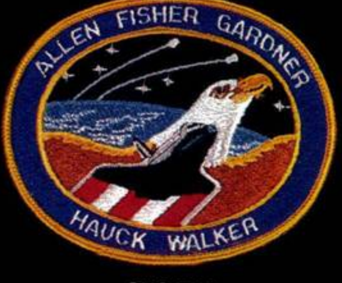
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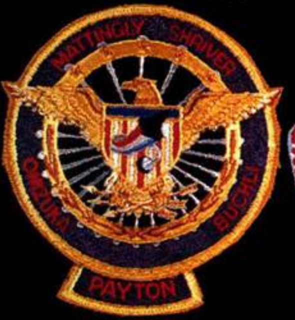
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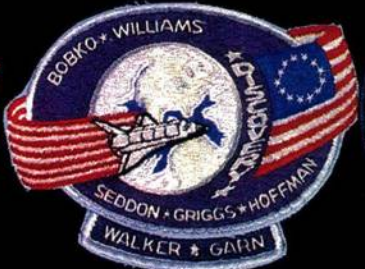
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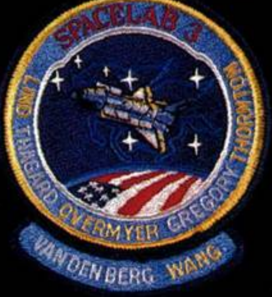
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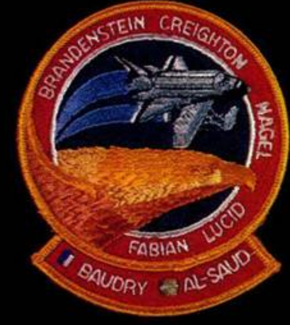
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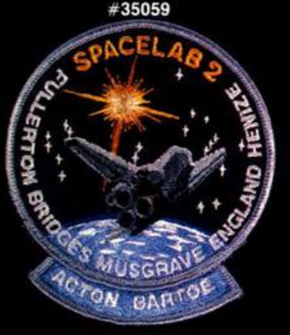
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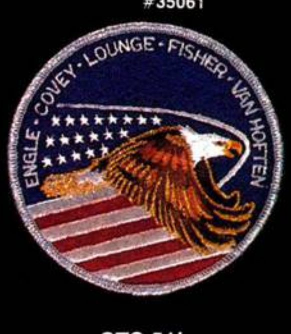
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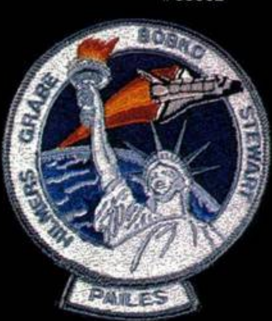
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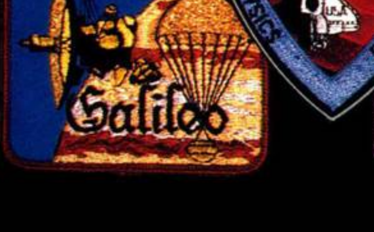

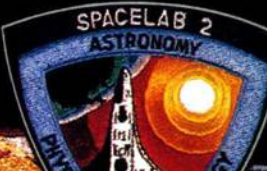
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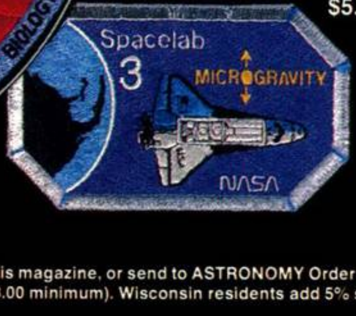
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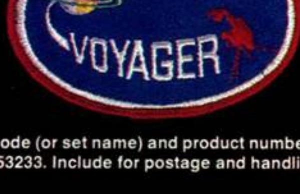

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Inside Orion's Stellar Nursery

A new infrared image reveals hundreds of young stars in the Orion Nebula's dense star-forming region.

by Jeff Kanipe

Using one of the latest marvels in astronomical instrumentation, astronomers have penetrated layers of dust in the famous Orion Nebula to photograph one of the inner sanctums of star formation.

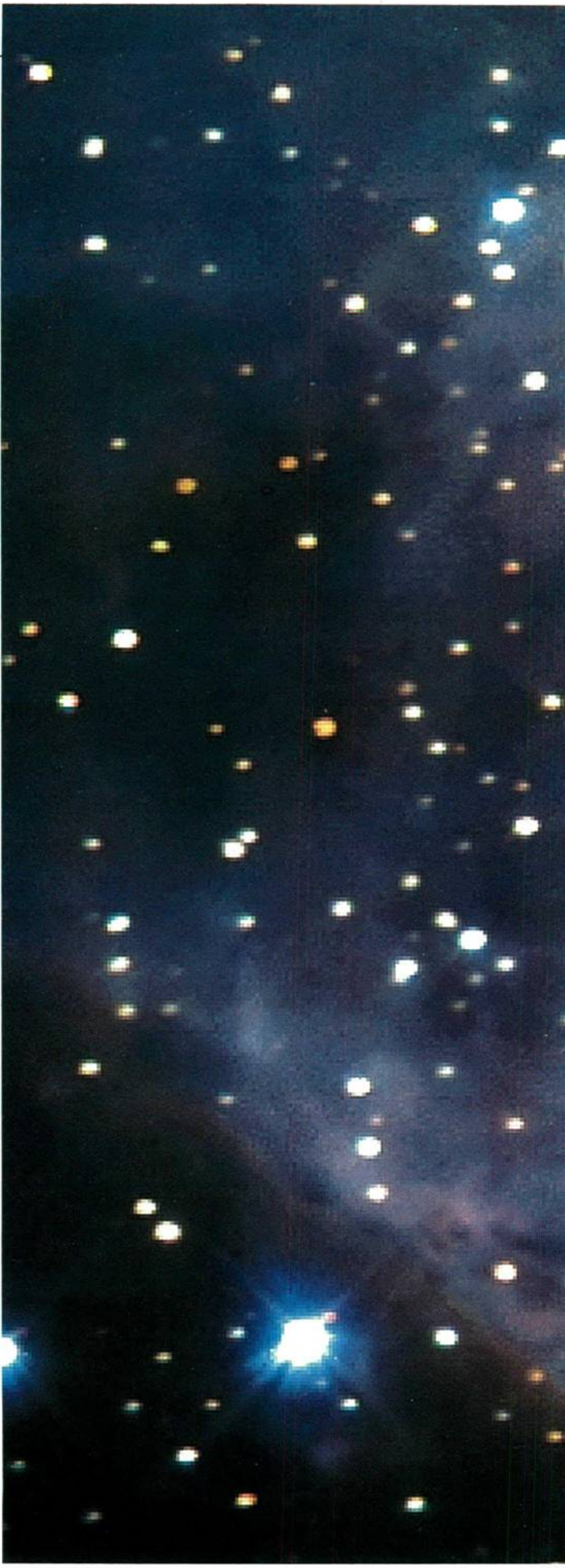
The photograph at right was taken with an electronic infrared array camera. The camera is similar to the charge-coupled devices used by optical astronomers but consists of four thousand detectors receptive only to near-infrared radiation. Interstellar dust is transparent at infrared wavelengths, but until refinements were made about two and a half years ago, infrared sensors lacked the sensitivity and efficiency to resolve discrete sources.

In December 1987, Mark McCaughrean of NASA's Goddard Space Flight Center, Greenbelt, Maryland, and Colin Aspin of the Joint Astronomy Centre, Hilo, Hawaii, coupled a 62- by 58-pixel infrared camera to the 3.8-meter United Kingdom Infrared Telescope atop Mauna Kea in Hawaii and took 145 small images of this region through each of three near-infrared filters. Then they processed and combined all 435 images in a computer to form a color composite. Hot sources were color-coded blue; cool, dusty sources were coded red.

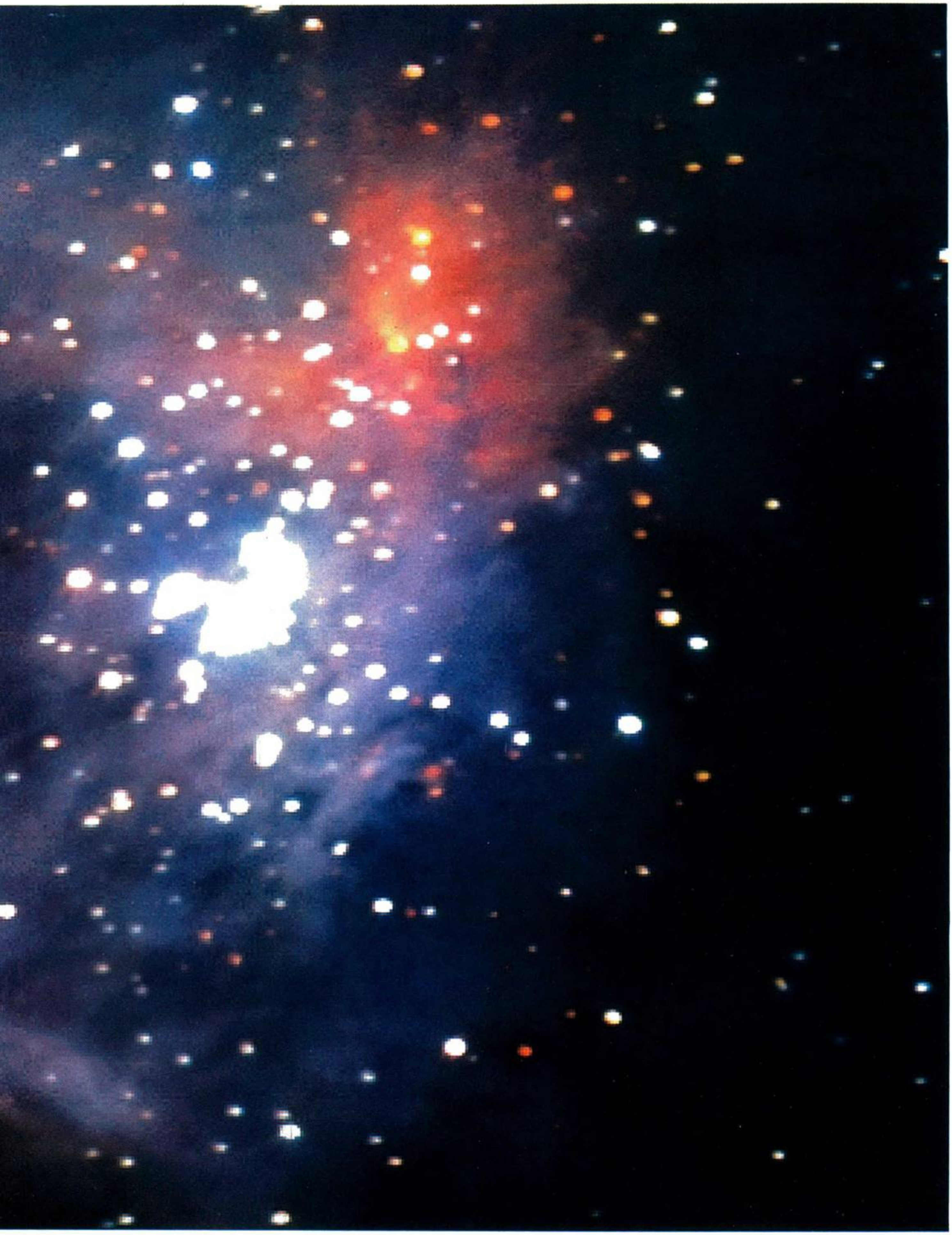
The photo covers an area only 5 arcminutes square but depicts much of the star-forming action in the heart of the nebula. The expanse between the lower left and upper right corners of the photo corresponds to less than two-thirds the distance between the Sun and our nearest stellar neighbor.

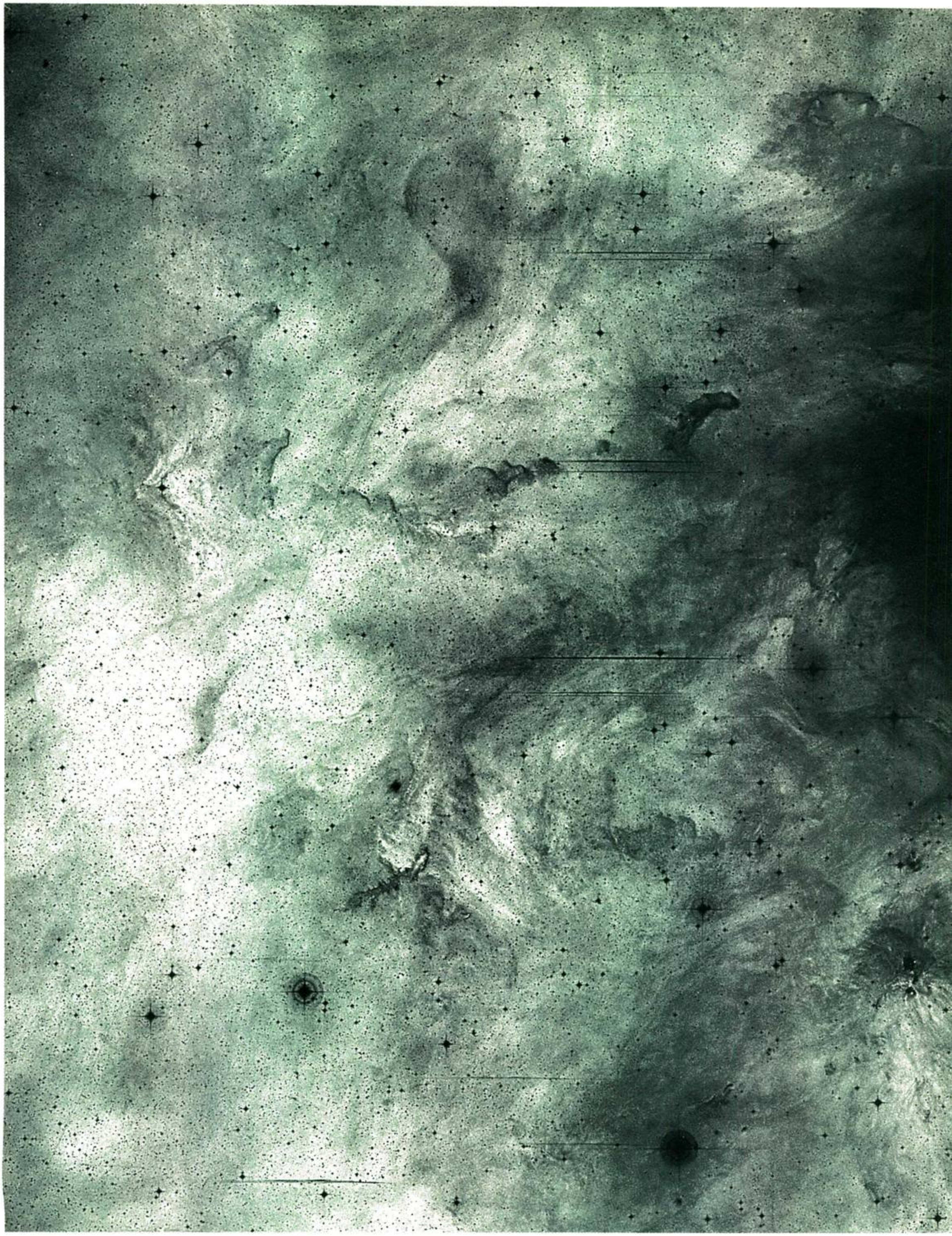
The image reveals a cluster of nearly five hundred mostly low-mass stars — of which less than one-fifth are visible at optical wavelengths — centered on the Trapezium, a nexus of four massive blue stars responsible for ionizing the Great Nebula. Most of the members of this embedded cluster, by astronomical standards, were born only yesterday — less than a million years ago. This, along with its size, makes the Trapezium cluster the densest young cluster known.

One of the most prominent features in the photo is a bar of nebulosity in the lower left of the frame. "The bar is a slightly foreground object that is difficult to appreciate in two dimensions," said McCaughrean.



A CLUSTER OF YOUNG STARS, unseen at optical wavelengths, swarms about the bright Trapezium stars in this near-infrared image of the central Orion Nebula. The stars are estimated to be about 1 million years old.





NEW STARS may one day condense out of the dusty filaments swirling around the Orion Nebula (dark area).

"Imagine that the Trapezium stars are sitting in the center of a cavity on the front face of a cloud, with the cavity open toward us, and that there are some edges coming up around one opening of the cavity. Those edges form the bar; it's a build-up of dust and gas that hasn't been pushed away yet."

The eye is also drawn to the ruddy region to the upper right of the Trapezium. This region, which is obscured from view at optical wavelengths but completely dominates the Orion Nebula at far-infrared wavelengths, is a site of recent star formation. Specifically, there are two bright yellow sources within this red region. The upper one is called Infrared Compact Source 9 (IRc9); the lower one is known as the Becklin-Neugebauer object, or BN for short.

BN is probably a single, almost-main-sequence star lying behind other clusters of infrared sources known collectively as the Kleinmann-Low Nebula, or KL, which is seen just below BN. "The molecular cloud in which the BN-KL sources are located is only a parsec or two deep," McCaughrean said, "and the sources are only a tenth of a parsec into the cloud. In several thousand years, these sources may break out of the cloud and form an ionized hydrogen nebula of their own."

Although BN is the brightest source in the region at near-infrared wavelengths, the energetics in the region is actually dominated by one of the KL sources. Designated IRc2, it is the barely visible red smudge just below and to the left of BN. "When you look at this region at longer wavelengths," said McCaughrean, "IRc2 comes belting through. Overall, it is 5 to 10 times more luminous than BN." This makes IRc2 one of the powerhouses of the nebula.

Farther to the upper right of IRc2 and BN are some red streamers or fingers. "These correspond closely to jets of molecular hydrogen emission," McCaughrean said. "If you trace them back, they appear to emanate from IRc2, commonly thought to be responsible for them. However, it has been suggested that the bright, near-infrared source IRc9 might be responsible for these streamers."

Some astronomers think that the red streamers constitute one of two lobes of ejected material from IRc2. Part of the other lobe is visible as the reddish patch to the left of BN. "Unfortunately," McCaughrean said, "there's a great swath of dust covering the other part of the lobe. You can see part of this as a 'finger' of darkness coming up just to the right of BN." An hourglass-shaped nebula such as this is called a bipolar reflection nebula. In this case, the distinctive hourglass shape arises from gas flowing out from both poles of the newly formed star. The star itself sits within an edge-on disk of dust, but it also illuminates the ejected cloud of dust and gas.

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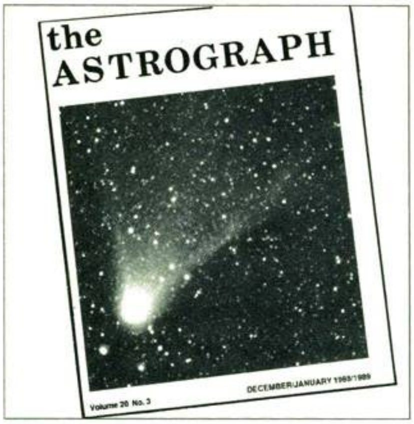

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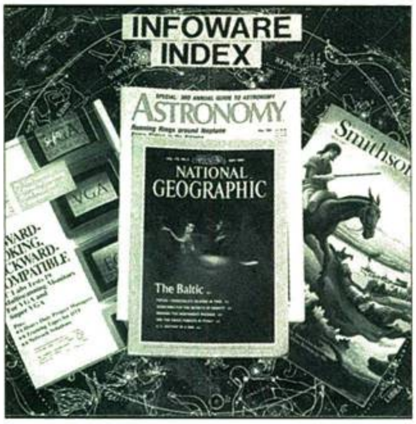

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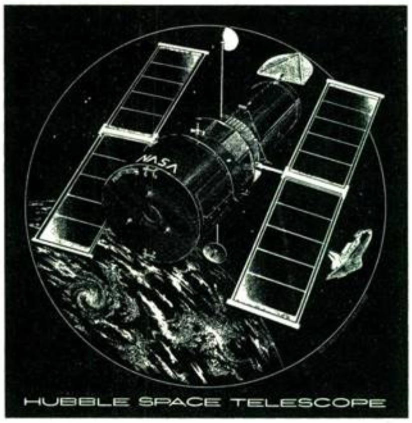

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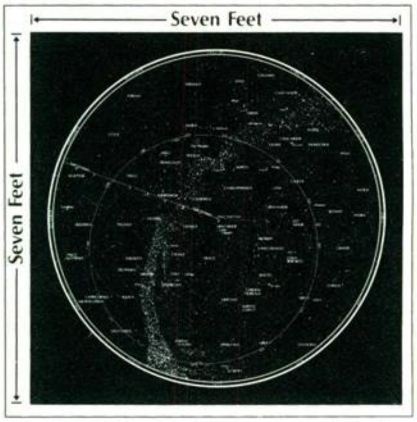

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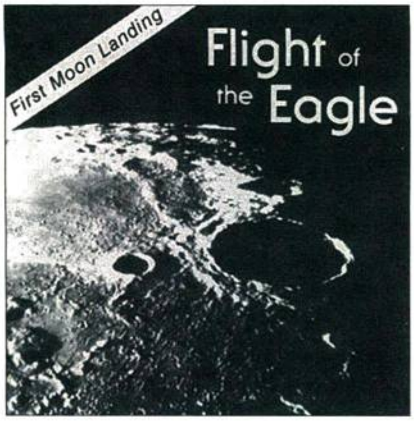

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The Day the Sun Cut Loose

Solar astronomers will not soon forget the events of March 1989 when the biggest flare in nearly thirty years erupted on the Sun.

by Gerrit Verschuur

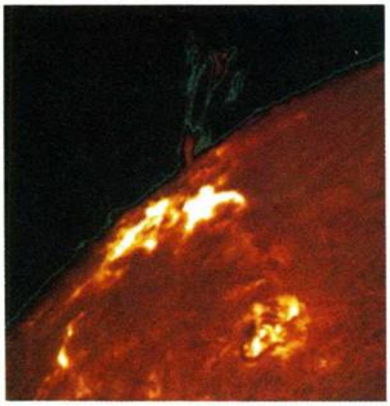
Few people in the world realized it at the time, but during two weeks in March the magnetic field that cocoons our planet suffered an unprecedented assault of wave upon wave of energetic particles from the Sun. The source of the storm was designated by solar astronomers as active region (AR) 5395, a locus of unusually bright solar flares in the Sun's upper chromosphere. Unlike previous solar flares, AR 5395 quickly distinguished itself as one of the most powerful flares in the past twenty-nine years, and one of the top three since records of solar energy output began 130 years ago.

The onslaught culminated on March 13, when an enormous solar shock wave slammed into Earth's magnetosphere with the force of a megaton bomb. The magnetosphere buckled and was driven back from its usual stand-off distance of 34,000 miles to within the orbit of the geostationary satellites (22,000 miles high).

Radiation detectors on these satellites recorded wild surges as fast-moving solar electrons, protons, and magnetic fields filled space that hours before had been calm. In the days following the March 13 blitz, Earth's magnetosphere continued to suffer hammer blows to its sunward face but finally held 14,000 miles above us. At the storm's height, the magnetopause — the boundary defining the limit of influence of the terrestrial magnetic field — had shrunk to half its usual size.

As the storm abated, the shield slowly inflated again. But there was more to come. For two weeks the chaos originating in active region 5395 did not let up. Several more times the magnetopause was driven inside the geosynchronous distance; each time the onslaught was resisted. Those weeks in March may have been Earth's greatest test of magnetospheric strength since humans began to measure the influence of the Sun on our planet.

It all began on March 4 at 16h20m UT (11:20 a.m. EST), said Judy Nelson, solar forecaster for Goddard Space Flight Center. A surge of activity was first noticed on the Sun's northeast limb at Ramey Solar Observatory operated by the Air Force, which has an interest in knowing when solar storms are liable to disrupt long-distance communication.



PLASMA EXPLODES from the powerful class X15 flare produced by active region 5395 on March 6, 1989.

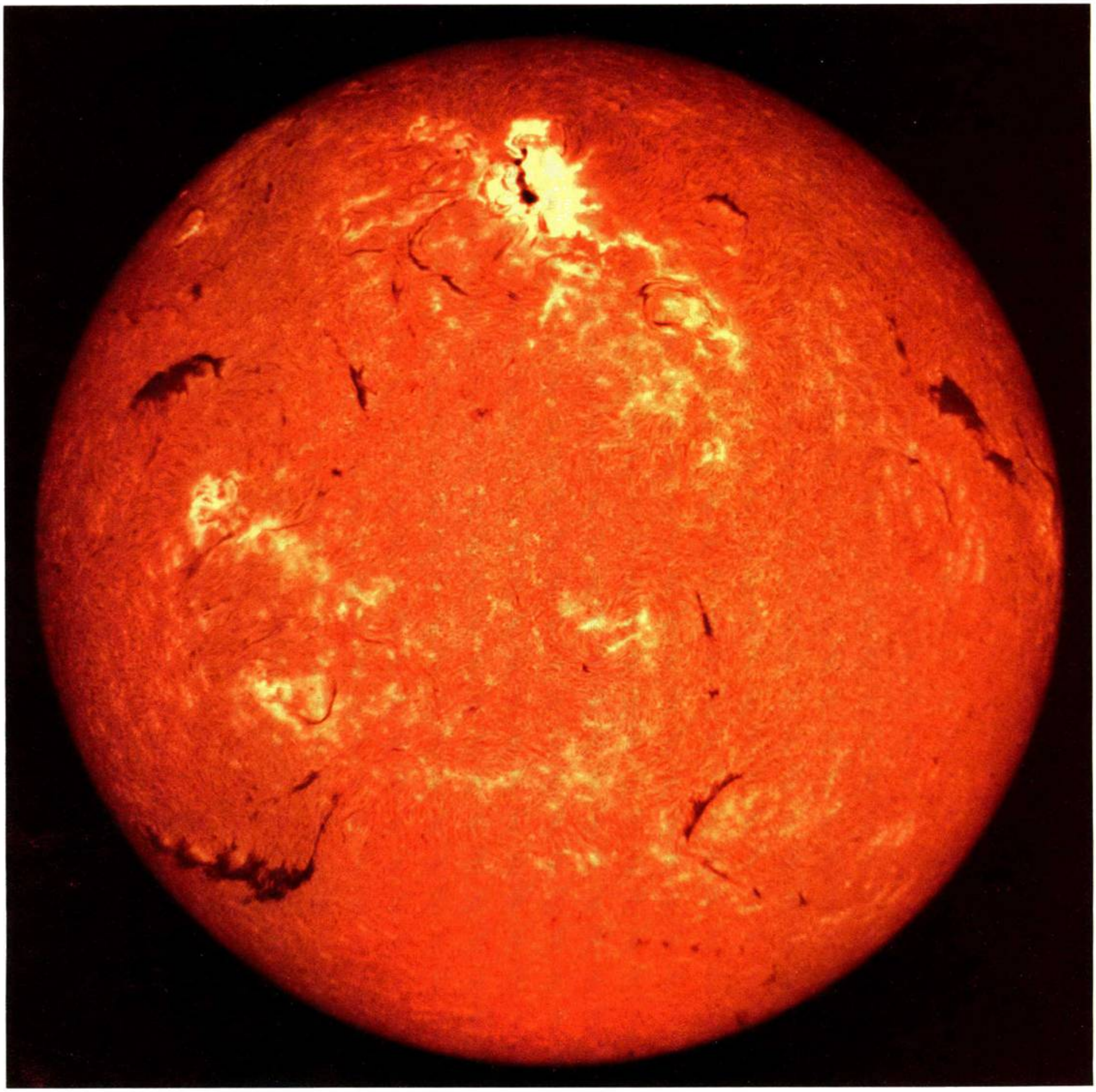
Even when the active region was still behind the limb, flare activity warned of its approach, said Kent Doggett, space forecaster in the Space Environment Laboratory at the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colorado. "Region 5395 was remarkable in all respects," he added. "Its sunspots were highly complex, a sure indicator of twisted magnetic field structures. Such a region has the potential for generating violent outbursts as fields twist and turn and recombine with each other to create explosions that drive particles into space."

As region 5395 slid into view, it dominated the interest of every solar astronomer and geophysicist in the world. Pat McIntosh, project leader for solar physics research at NOAA, recalled that they knew something big was brewing because the region was unusually far from the solar equator, at 55° north latitude. "I don't know of other flares that extended so far north," he pointed out after the displays had ended.

On March 6 an enormous explosion swept a huge volume of gas out of the Sun. The explosion created a blast of x-rays that overwhelmed detectors aboard the *Geostationary Orbiting Environmental Satellite* (*GOES*), which is used to monitor the Sun to give early warning of impending activity. The explosion lasted ten hours, compared to about thirty minutes for a normal one. "It was labelled an X15 flare," said McIntosh. "That's the top of the scale and is the largest we can measure. However, it could have been an X20," he speculated, still awed by the intensity of the event.

Joan Schmelz, a scientist with the team that operates the x-ray imaging device on the *Solar Maximum Mission* satellite, said that the satellite's instruments were quickly trained on the active region. "Our data showed that the X15 flare temperature reached about 20 million kelvins," she reported, which is far above the 1 million kelvins that is normal for the lower corona where the explosion originated.

Kent Doggett reported that the flare produced an unprecedented burst of radio emission. "At 10 centimeters it was 200 times and at 245 megahertz [120 cm] it was 2,000 times brighter than the Sun normally is." Such intense radio bursts severely affected communication with satellites in geosynchronous orbit because of the Sun's position in the sky at the vernal



OVER 100,000 MILES ACROSS, the region that spawned the powerful flares could have comfortably held a dozen Earths.

equinox. During the equinoxes the Sun is located above the equator and from the perspective of ground stations appears in roughly the same direction as the satellites. The presence of the enormously powerful radio bursts therefore caused widespread interference on many television cable networks.

According to Joe Kinches, another forecaster in the Space Environment Laboratory, the first shock wave struck Earth at 17h55m UT (12:55 p.m. EST) on March 8, fifty-two hours after the spectacular X15 flare. The proton counts on the *GOES* satellite quickly rose and then fell, only to rise again for the next twenty-four hours. There were so many protons involved that the scientists could not sort out how many separate clouds of particles struck Earth. Not until March 14 did the counts fade away again. Never before had such a long-lasting solar event been recorded.

As active region 5395 moved across the solar disk, it erupted with ten more class X flares and sixty-four class M flares. (Three letter classes — C, M, and X, in order of increasing strength — are subdivided into at least ten categories.) A total of 195 visible flares were counted between March 4 and 19. At one time (March 13) this active region had seventy-one sunspots, which covered an area equivalent to forty Earth diameters. At the same time, another seventy sunspots freckled the rest of the Sun.

Worldwide interest among astronomers in happenings on the Sun was heightened by an enormous X4 flare on March 10. It was rated a 4B by visual observers, the top of a scale of fifteen levels referring to a flare's area and brightness. It was physically larger than the X15 event, which scored 3B.

"The continuous release of energy from this flare was incredible," said McIntosh. "It held at a level of X4 for forty-five minutes without fading. I have never seen anything like it in my twenty-five years in the business. The optical flares associated with 5395 may have been the largest ever recorded."

Joe Hirman, manager of the Space Environment Services Center, summed up the four stages of flare-related events. "First magnetic energy around the sunspots is converted into mechanical energy as particles are explosively ejected from the Sun. Associated electromagnetic energy in the form of x-rays, visible light, and radio reaches Earth eight minutes later. Solar cosmic rays — high-energy protons — arrive after about thirty minutes and are followed by a magnetic shock that impacts Earth about two days after the flare."

Chris St. Cyr, a scientist on the team that operates the white-light coronagraph aboard *Solar Max*, described the violent expulsion of clouds of particles from flares. "We see them as coronal mass ejections travelling at more than a million kilometers per hour." Although coronal mass ejections contain very little mass — about one-thousandth of the mass of Mars' moon Phobos — the energy tied up in the particles and magnetic fields is prodigious. A large flare releases energy equivalent to a *10 billion* megaton bomb.

Fortunately for us, only a tiny fraction of the flare energy impinges Earth because our planet presents such a small disk size due to our enormous distance from the Sun. Nevertheless, when the ejecta from the March 10 explosion reached us, they triggered magnetometers in Fredericksburg, Virginia, into wild activity. The geomagnetic storm — sudden variations in Earth's magnetic field due to solar flares — began at 01h28m UT on March 13 (8:28 p.m. EST on March 12) and lasted for five days. Jo Ann Jocelyn, a space scientist at NOAA, described this storm as "severe" and said that only twice since measurements began 130 years ago have more violent storms been observed. The top two occurred on September 25, 1909, and September 18, 1941. The March 10 event tied for third place with a storm on November 13, 1960.

When Earth's magnetic field is driven inward by the impact of the particle clouds, which hit head-on at nearly 2 million miles per hour, field compression generates enormous electrical currents in the magnetosphere. These, in turn, induce currents in long, metallic objects, such as pipelines, railroad tracks, and electrical power lines. If safety systems weren't installed in the Alaska pipeline, for example, the huge oil conduit would have experienced a damaging one-thousand amp current. Safety devices, however, assure that such currents quickly leak to ground.

Power lines at northern latitudes are similarly protected but, nevertheless, utility companies require warning about impending storms so that they can take steps to protect their systems. Geomagnetically induced currents fluctuate on time scales of several minutes, and high-voltage transformers are not designed to tolerate these low frequencies.

One major utility appeared to have suffered the brunt of the solar cataclysm. On March 13, Hydro-Quebec lost 9,450 megawatts of power when five lines from their James Bay facility were simultaneously overloaded. This started a chain reaction that left 6 million Canadians without electricity. In the United States several utilities also reported problems, but none lost power.

If they are prepared, engineers can cope with rogue surges by reducing their power load. Thus they keep a close watch on forecasts of geomagnetic storm activity prepared by the Space Environment Services Center of NOAA. Chris Balch of the SESC said they issued thirty-seven rapid alerts — urgent warnings associated with class M5 flares or greater — and 415 normal alerts to their customers during the two weeks in March.

Others who rely on solar forecasters are satellite operators. Clouds of solar particles impinging on satellites can as Earth's, the particle clouds are guided harmlessly around the planet by the magnetopause, which stretches to form a magnetic tail reaching nearly 4 million miles into the night sky. However, oppositely directed fields love nothing better than to link, couple, and then annihilate each other.

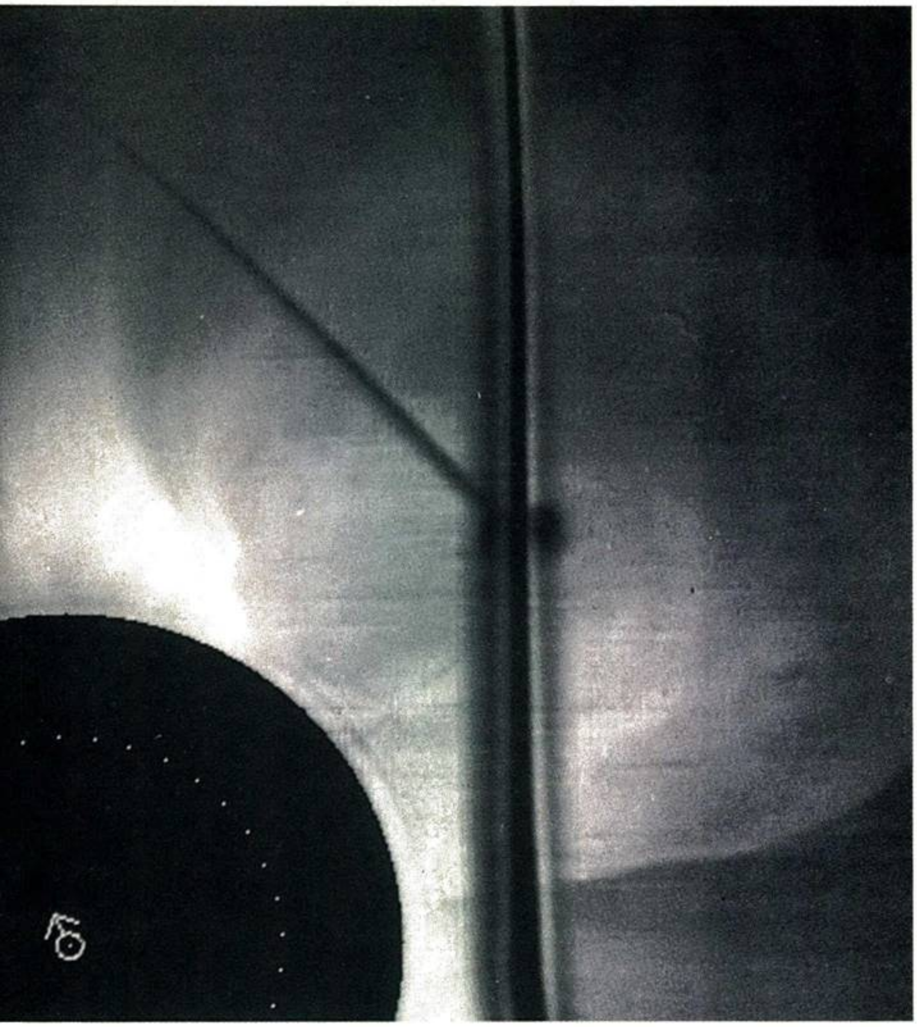
The effects of the solar magnetic fields on the magnetosphere are complex. Field loops created by reconnections quickly disappear, much like the proverbial snake swallowing its tail. When a field loop pops out of existence, its energy is converted into rapidly moving electrons and protons that hasten down the undisturbed field lines toward the south and north magnetic poles and into the auroral regions. There they collide with atoms and molecules 50 to 600 miles up in the atmosphere.

In March the energy stoking Earth's magnetosphere was so great that the red auroral glow of protons striking atmospheric oxygen atoms was seen as far south as the Bahamas and Guatemala. Indeed, for many people all over the Northern Hemisphere, the climax of this series of solar events was the aurora on the nights of March 13 and 14.

"The present eleven-year sunspot cycle (number 22 since counting began) has all the hallmarks of being the largest ever," reported Pat McIntosh. "If the next spike of activity is above the present one [which may have occurred by the time this article is published], this cycle will break all records." He added that the maximum is expected to occur two to twelve months from now.

The *Solar Max* satellite was able to join with ground-based solar observatories around the world to witness this series of spectacular flares. Ironically, its demise was hastened by the active region it observed so closely. Radiation from the flares warmed the atmosphere, causing it to expand a little, thus slowing down every satellite caught in its embrace. Thus *Solar Max* fell a few more kilometers on its way to a fiery end, predicted for early October.

Active region 5395 was born on the farside of the Sun, and that is where it died. In early April it reappeared, but as a shadow of its former self. ☐



A RARE AURORA, triggered by the flares, burnishes the night sky over Cocoa, Florida, on March 13 (left). Five days later, *Solar Max* records a huge bubble of expelled coronal gas (above) twice the Sun's diameter. An occulting disk blocks the Sun's inner corona and surface (indicated by the dotted line at lower left).

create large voltages across the length of a satellite. These, in turn, can cause electrical discharges (miniature lightning flashes) that can alter the functioning of transistors or even destroy equipment. Several satellites had to be powered down until the worst was over.

Navigation satellite operators also pay very close attention to the Space Environment Services Center's warnings. Gary Heckman, chief of the Space Environment Services Center of NOAA, explained that these satellites are oriented by using gyroscope-like devices known as momentum wheels. If the spacecraft were struck by an unexpected gust of solar wind, not to mention a full fledged blast such as occurred on March 13, loss of control is a real possibility. "They depend on our forecasts," Heckman said. "Back-up momentum control systems are available for emergencies. With adequate warning the controllers can use the back-ups to weather the storms." As a result, no serious problems were reported during March, although one previously stable, classified satellite in low orbit began tumbling.

Although the space shuttle was in orbit at the time, the astronauts were relatively safe inside the craft, which was in a low-Earth orbit and did not come near Earth's polar regions where the consequence of the flare activity would have been most dangerous. The greatest harm to an astronaut would come if he or she were taking a space walk when the shock hit Earth.

"The trouble with these particular coronal outbursts," Ted Speiser of the University of Colorado said, "is that they carry a magnetic field oriented opposite to that of Earth, and this leads to severe magnetic storms. We don't really know why the field in the solar wind is sometimes directed one way and then another." Whatever the cause, the consequences are dramatic.

Usually, when the solar wind carries a field oriented in the same direction

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Gerrit Verschuur, a radio astronomer and science writer who lives in Bowie, Maryland, is the author of Interstellar Matters, *published by Springer-Verlag. Verschuur's article, "The Many Faces of the Sun," appeared in the March 1989 issue.*

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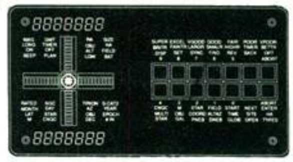

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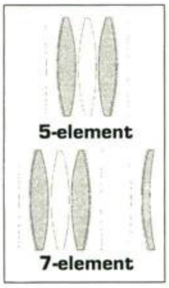

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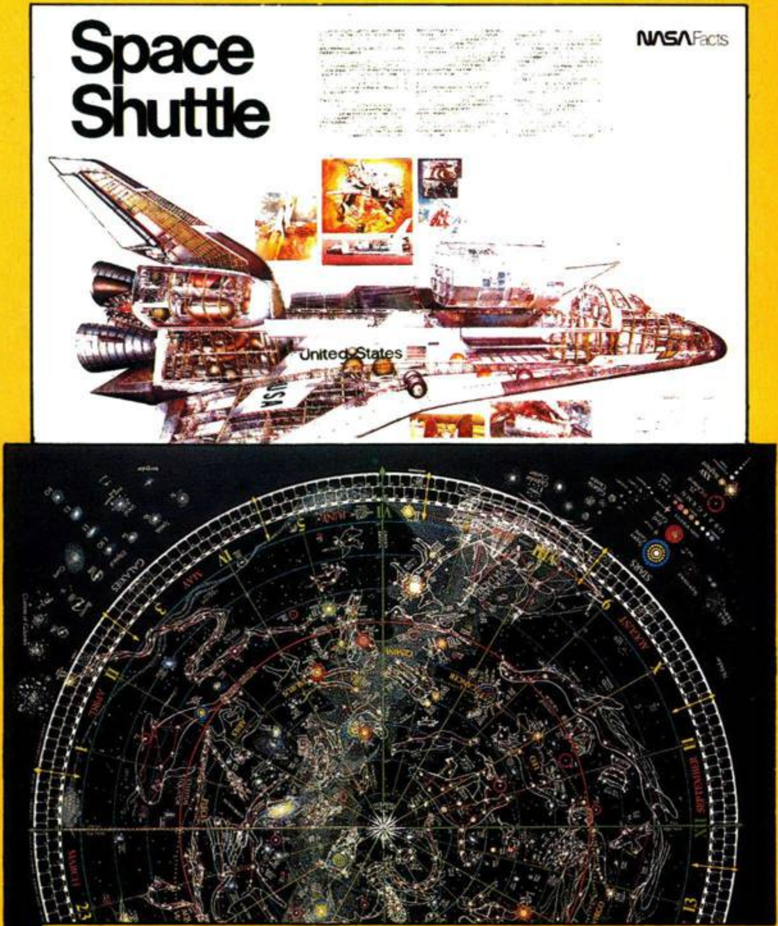

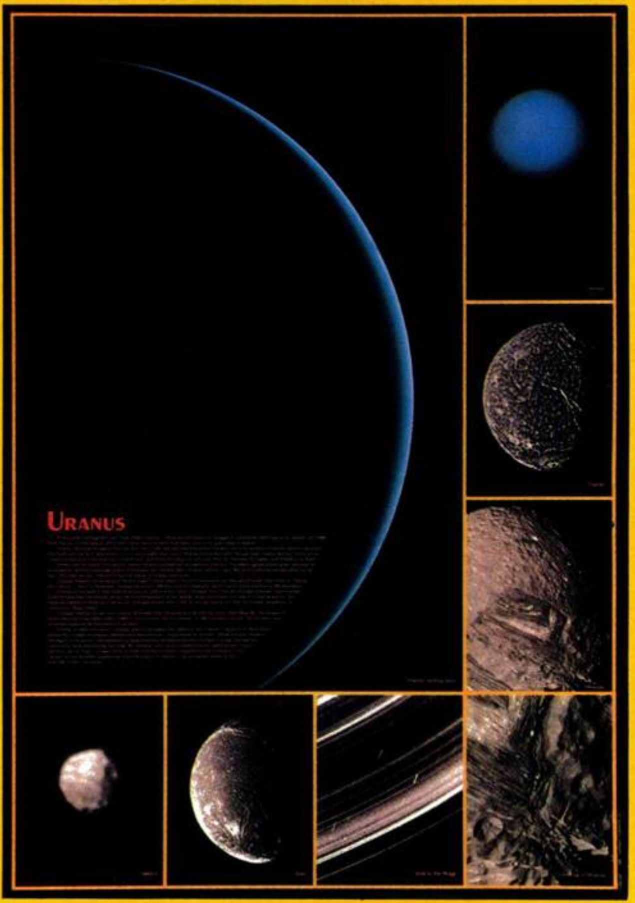

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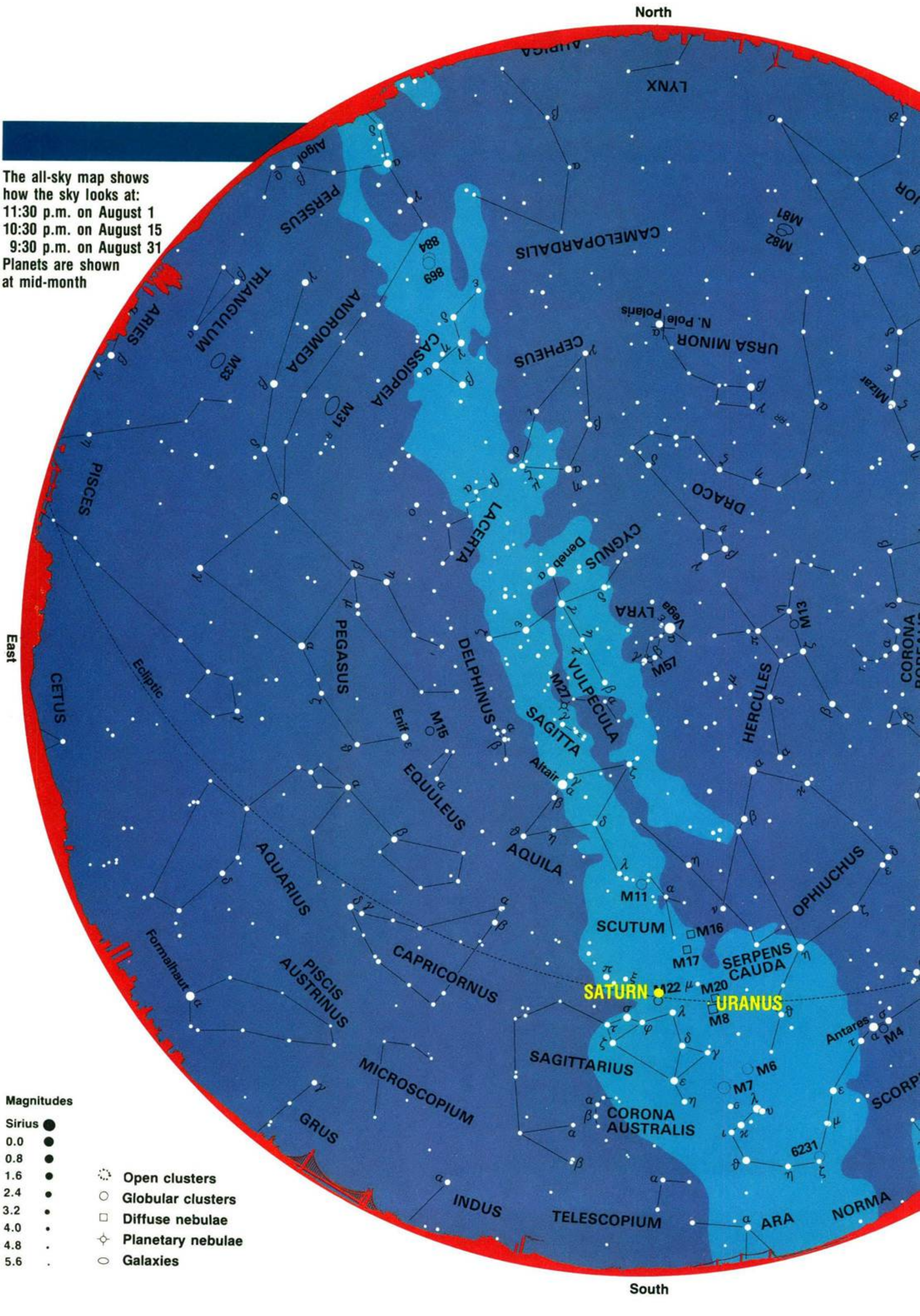
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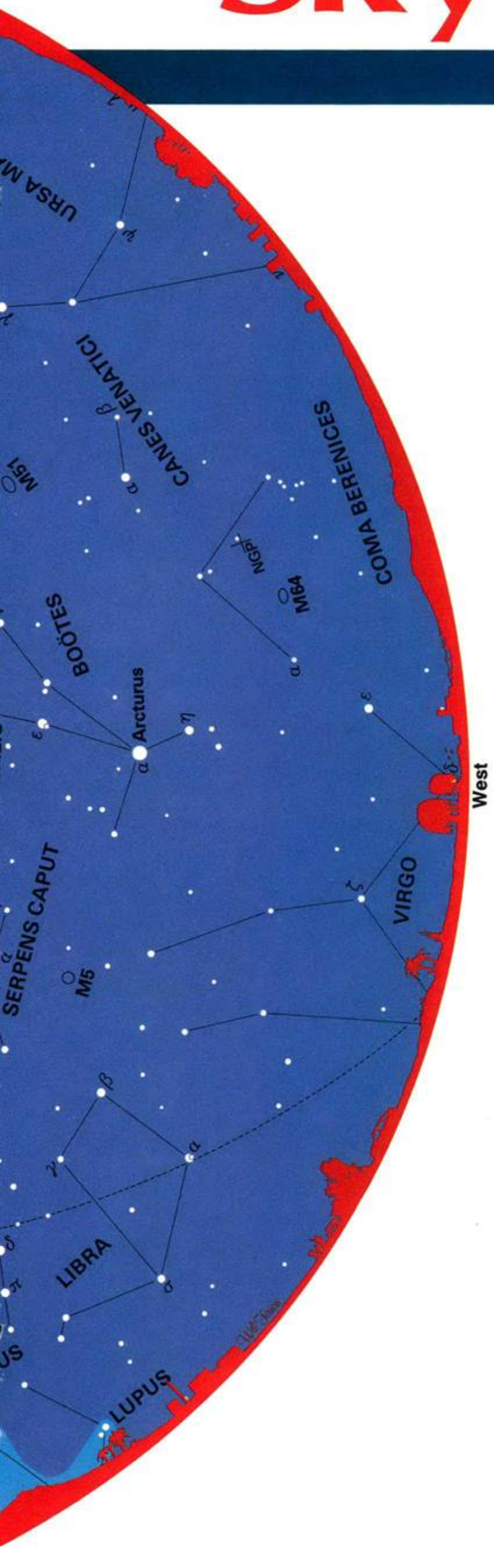


MOON ECLIPSED ON AUGUST 16/17

Observers in most of North America can see a total lunar eclipse after sunset on August 16. Observers in the eastern half of the continent can see all of the eclipse; the Moon rises with the eclipse in progress for observers in western North America.

PERSEIDS PEAK ON AUGUST 12

Your best view of the Perseid meteor shower comes in the predawn hours of August 12 after the Moon has set. Expect to see some fifty meteors an hour that morning and about half that number the mornings before and after the 12th.

MERCURY AND MARS TOGETHER

Mercury passes just 0.01° north of Mars on August 5. Observers with binoculars can see the two planets very close together low in the west about thirty minutes after sunset.

Dates and Times

1 New Moon is at 12:06 p.m. EDT

2 Mars passes 0.7° north of Regulus, noon EDT
The Moon passes 1.6° south of Mercury, 10 p.m. EDT

3 The Moon passes 0.9° south of Regulus, 3 a.m. EDT
The Moon passes 1.6° south of Mars, 4 a.m. EDT

4 The Moon passes 3° south of Venus, 9 a.m. EDT
Mercury passes 0.8° north of Regulus, noon EDT

5 Mercury passes 0.01° north of Mars, 6 p.m. EDT

7 The Moon is at apogee (251,467 miles from Earth), 11:23 a.m.EDT
Vesta is stationary

9 First Quarter Moon is at 1:28 p.m. EDT

10 Metis is at opposition

11 The Moon passes 0.6° south of Antares, 10 a.m. EDT

12 Perseid meteor shower peaks before dawn

13 The Moon passes 4° south of Saturn, 2 p.m. EDT

16 Full Moon is at 11:07 p.m. EDT; total lunar eclipse

19 The Moon is at perigee (225,912 miles from Earth), 8:31 a.m. EDT

23 Last Quarter Moon is at 2:40 p.m. EDT

26 The Moon passes 4° north of Jupiter, 3 a.m. EDT

27 Eunomia is at opposition

29 Mercury is at greatest eastern elongation (27°)

30 Victoria is at opposition

31 New Moon is at 1:44 a.m. EDT; partial solar eclipse

Eye on the Sky by Deborah Byrd

A SPLENDID LUNAR ECLIPSE

Observers in North and South America, as well as those in Europe and Africa, can see a particularly fine total lunar eclipse on the night of August 16/17. Totality — when the Moon is completely submerged in the dark umbral part of Earth's shadow — lasts 96 minutes, only 11 minutes less than the maximum possible. This eclipse is the longest since 1982 and its length will not be equaled again until 1993.

In North America eastern observers have the best view, but some stages of the eclipse are visible throughout the contiguous United States and Canada and in parts of Hawaii and Alaska. The eclipse begins at 9:21 p.m. EDT on August 16, when Earth's umbral shadow first touches the Moon's western limb. The shadow creeps slowly across the Moon's face until the entire Moon is covered at 10:20 p.m. EDT. The middle of the eclipse comes at 11:08 p.m. EDT.

Those east of a line from Del Rio, Texas, through central Kansas, to International Falls, Minnesota, can see all of the eclipse. For those west of the line the Moon rises while the eclipse is in progress. The Moon stays below the horizon for more of the eclipse the farther west you are, but even from the West Coast part of totality is visible.

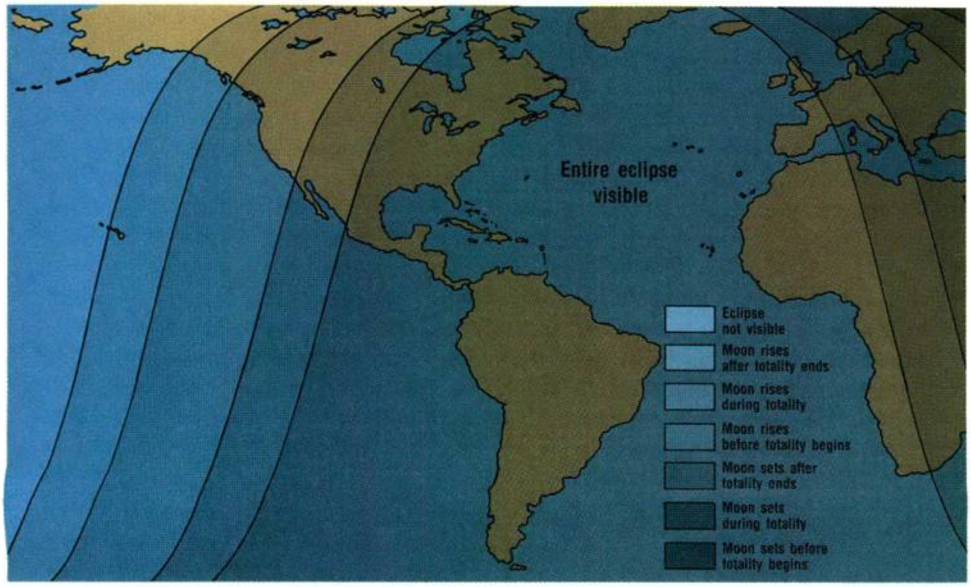
During the total phase of a lunar eclipse the Moon doesn't disappear entirely from view. Although Earth blocks direct sunlight from reaching the Moon, some light is refracted by Earth's atmosphere and strikes the Moon's surface. Atmospheric conditions worldwide at the time of an eclipse determine the Moon's color during totality. The color can be very dark, making the Moon nearly invisible, particularly when volcanic eruptions on Earth hurl large amounts of debris into our atmosphere. More often, though, the Moon turns an eerie reddish color.

A RED-HUED MOON hung high above Singapore during the February 20, 1989, lunar eclipse. Photo by Michael Toh Ho Sing. The total eclipse on August 16/17 promises similar good views for residents throughout the Western Hemisphere.

SUMMER'S BEST METEOR SHOWER

The impressive Perseid meteor shower peaks on the morning of August 12. From a dark site you can expect to see about fifty meteors an hour before dawn that morning and probably half that number before dawn on August 11 and 13.

Keep in mind that good sky conditions are as important for watching meteors as the strength of the meteor shower. This point was brought home to me during last year's Perseid shower. On the morning of August 11, I viewed the shower from an open field only a few miles west of the forest fires raging in Yellowstone National Park. Lights from an adjacent campground (where my two daughters lay sleeping in our van) also interfered. In an hour of watching, I saw only seventeen meteors. The following morning, after driving some five hundred miles west into Oregon, I had a much darker sky and counted fifty-nine meteors in an hour.


Entire eclipse visible
Eclipse not visible
Moon rises after totality ends
Moon rises during totality
Moon rises before totality begins
Moon sets after totality ends
Moon sets during totality
Moon sets before totality begins

Watching the Perseids can become a wonderful summertime ritual. This year, as always, you'll get a better view if you leave the lights of the city behind. Watch in the hours close to dawn after the waxing gibbous Moon has set and enjoy.

A TWILIGHT GATHERING

On August 2 a very slender crescent Moon comes into view after sunset for those with a clear western sky. If you spot the day-and-a-half-old Moon, it can guide you to a tight grouping of two planets and a star low in the west.

The brightest of the three objects is Mercury at magnitude −0.6. The star Regulus is next brightest at magnitude 1.3. And the third object is Mars, now at its faintest for the year at magnitude 1.8.

The objects' low altitude makes them very difficult to see — look no later than about thirty minutes after sunset. Binoculars will help to reveal the three shining points below and to the right of brilliant Venus and close above the young Moon on August 2.

In the days afterward the Moon ascends in the evening sky and Regulus sinks toward the Sun, but Mercury and Mars linger briefly, edging ever closer together. On August 5 they pass within 0.01° of each other during the afternoon hours for North America. The two remain close that evening, so if you have binoculars and love a challenge, look for them as soon after sunset as possible.

TWO METEORS STREAK across the northern sky during 1985's Perseid meteor shower. This year's shower should produce up to fifty meteors an hour before dawn on August 12. Photo by Harry Litts.

AUGUST'S PLANETS

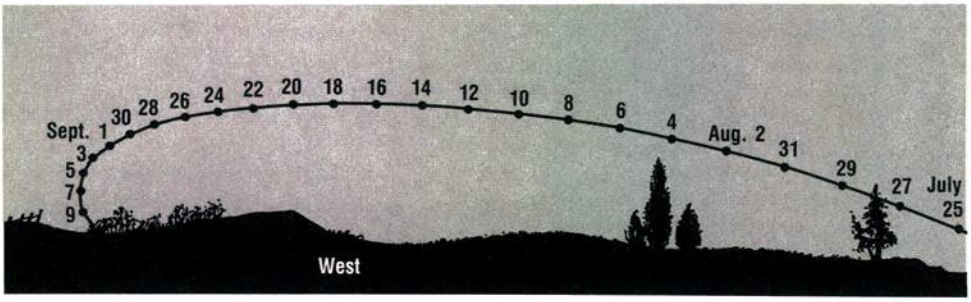
Mars sinks into the sunset glow this month, ending the Red Planet's best apparition in recent memory. You wouldn't know it to see Mars now, but a year ago it was a fiery red beacon in our sky, outshining even mighty Jupiter. At that time Mars was closer to Earth and brighter in our sky, at magnitude −2.8, than it had been since 1971.

This month Mars shines at magnitude 1.8 and hovers so low in the west after sunset that you'll have a hard time seeing it at all. Your best chance comes in the first few days of August when the planet is close to brighter Mercury and the star Regulus.

Of these three objects, Mercury is brightest at magnitude −0.6, but it is already fading rapidly as the month begins. This is one of those paradoxical apparitions of Mercury when the planet is far from the Sun in our sky yet only marginally visible.

Mercury reaches greatest elongation on August 29, just four days after the planet is at aphelion (when it is farthest from the Sun in its 88-day orbit). This coincidence explains why Mercury appears so far from the Sun on the dome of our sky, 27° away at this elongation.

But the time of year on Earth is not advantageous for viewing Mercury. During August the ecliptic — the apparent path of the Sun across the sky followed closely by the Moon and planets — is nearly parallel to the western horizon in the evening as seen from the Northern Hemisphere. Mercury's large separation from the Sun goes unnoticed by us because each day's increasing distance translates in our sky to a movement along the horizon. Meanwhile, Southern Hemisphere observers witness the year's best apparition of Mercury in August and September because the ecliptic is nearly perpendicular to their horizon.



MERCURY LIES LOW in the west on August evenings, reaching a maximum altitude of 5° thirty minutes after sunset on August 17.

Venus still hasn't ascended to any great height in the western twilight sky, but the planet is so bright it is conspicuous anyway. It shines at magnitude −4.0 by the end of August and will grow steadily brighter, and get a little higher in the sky, over the next few months.

Prominent in the south-southeast at the end of evening twilight, Saturn is the sky's lone bright planet until Jupiter rises well after midnight. Saturn now appears slightly fainter than it did at last month's opposition, when Earth passed between it and the Sun. It continues to fade during August, from magnitude 0.2 to 0.3. Saturn still resides in the constellation Sagittarius, where it remains throughout the year.

Jupiter returned to the morning sky last month, and at the beginning of August it dominates the sky before dawn, rising fully three hours ahead of the Sun. By the end of the month, with the Sun coming up later and Jupiter rising earlier, the giant planet is up more than five hours before the Sun.

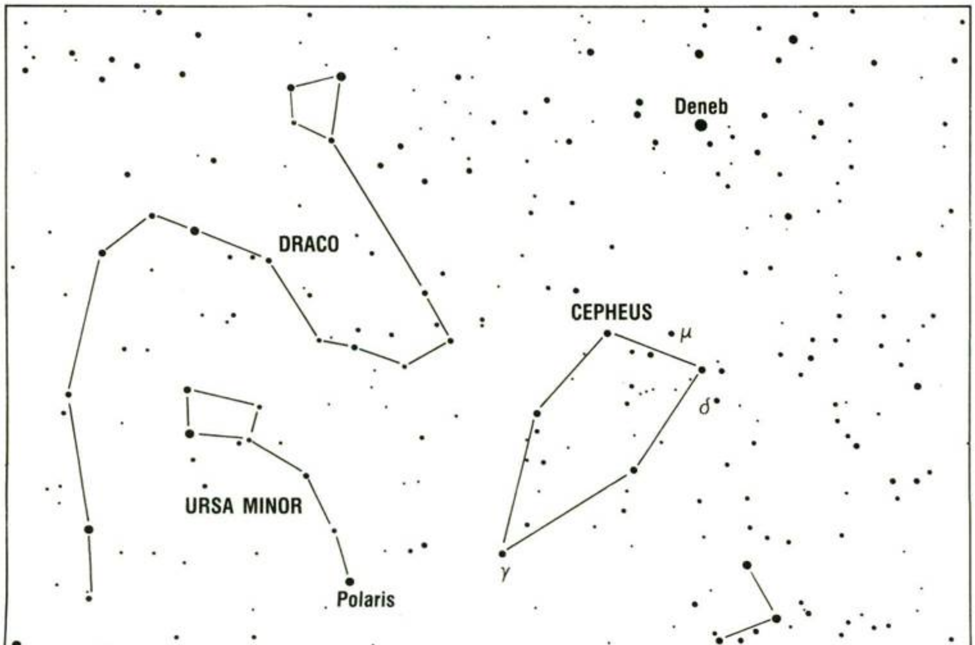
AUGUST'S STARRY SKY

Cepheus is a large, relatively faint constellation located near the north celestial pole. It is so near the pole, in fact, that for most latitudes in the United States it is circumpolar and can be seen in the vicinity of the pole star on any clear night. It appears highest in the sky during the evening hours in late summer and autumn.

Although Cepheus is faint, it has a distinctive shape that makes it easy to locate. It resembles the house we all drew as children — and that children continue to draw — with a square for the base and a triangle on top for the roof. In the case of Cepheus, the tip of the roof (Gamma [γ] Cephei) points generally northward toward the pole star Polaris in Ursa Major. If you watch the constellation's changing position throughout the night and throughout the year, you'll get a good illustration of how stars move around the pole.

In Greek mythology, Cepheus was an Ethiopian king, part of the Royal Family of the Sky that also included Cassiopeia, the queen, and Andromeda, their daughter. It was Cepheus who had to chain his daughter to a rock by the sea to be devoured by the whale (Cetus) in punishment for his wife's claim that she and Andromeda were more beautiful than the sea nymphs. In the myths, the hero Perseus saved Andromeda just in the nick of time. Cepheus then granted him Andromeda's hand in marriage.

CEPHEUS THE KING rides high in the north late on August evenings. Look for the "house-shaped" constellation above much brighter Cassiopeia and to the right of the pole star Polaris.



Cepheus contains two of the sky's more famous variable stars, Delta (δ) and Mu (μ) Cephei. Delta varies regularly in brightness, from magnitude 3.5 to 4.4 and back again, with a period of 5 days, 8 hours, and 48 minutes. If you watch carefully, you can notice Delta's change in brightness by comparing it with that of nearby stars.

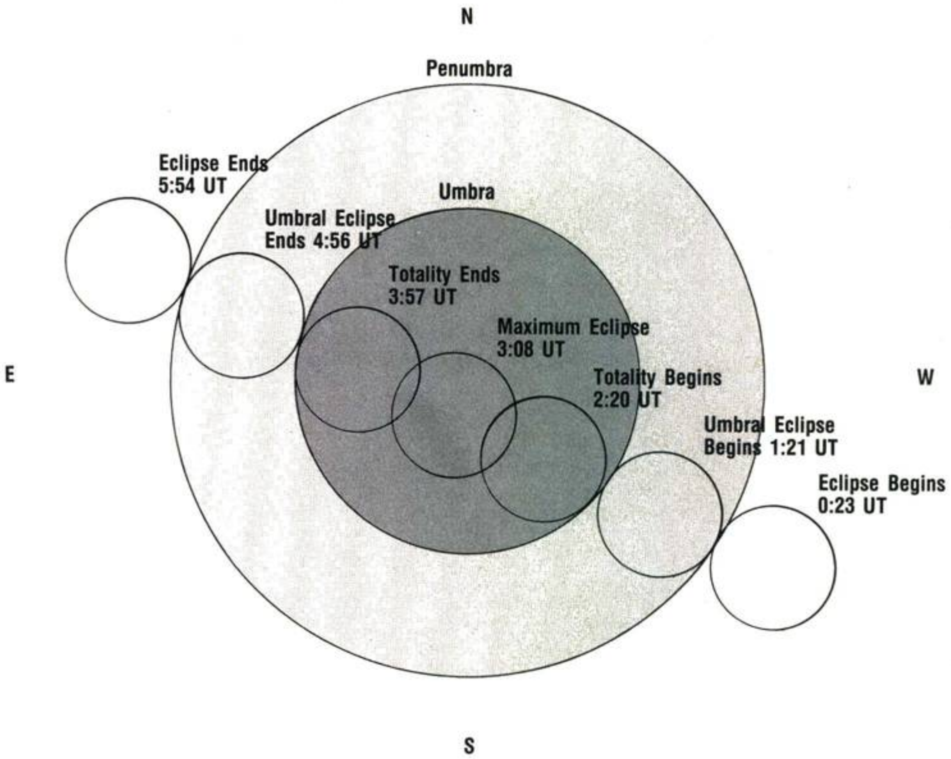
Mu Cephei is a red supergiant star less famous for its variability than for its color. The star is the reddest naked-eye star in the northern sky. Dubbed the "Garnet Star" by William Herschel, the star's tint is noticeable to the naked eye and quite striking in binoculars. Mu, which varies between 4th and 5th magnitude with a period of about two years, is also one of the most luminous stars known. Why not take a look at this colorful star the next time you're out stargazing? □

Through the Eyepiece by Rick Shaffer

OBSERVING THIS MONTH'S LUNAR ECLIPSE

On the night of August 16/17, the Moon slips into Earth's shadow and observers will witness a total lunar eclipse. The entire eclipse is visible from the eastern coast of North America, the Caribbean, and Central and South America. In the western half of North America the Moon rises after the eclipse has begun. (See the map on page 58 to find out how much of the eclipse is visible from your location.) To see as much of the eclipse as possible, choose a site with a low and unobstructed horizon toward the east-southeast, the direction in which the Moon rises.

Whether you're at home or vacationing, invite your friends, neighbors, relatives, or fellow campers to watch the eclipse with you. To give your guests a general view of the eclipse, consider using 10x70 or 11x80 binoculars mounted on a tripod. The best type of tripod is one that lets you raise and lower the central column to accommodate viewers of different heights. It also helps if you set the tripod up so that people can view while they're seated.



THE LONGEST LUNAR ECLIPSE in seven years occurs on the night of August 16/17. Times are in universal time on August 17; to convert to EDT subtract 4 hours, for PDT subtract 7 hours.

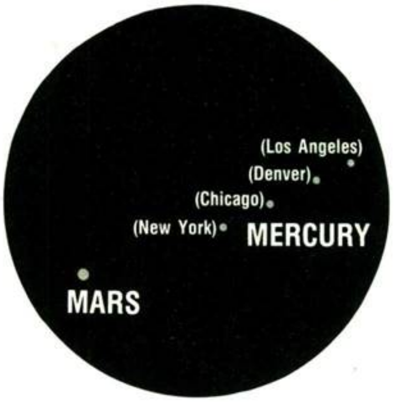
To show lunar craters as they are swallowed up and uncovered by Earth's shadow, a telescope at a power of 100x to 175x works well. Remember to brush-up on your crater identification skills ahead of time, because people often ask the names of the craters in the eypiece.

Even when the Moon is completely immersed in Earth's umbral shadow, at least a faint illumination plays on the lunar surface. This is because sunlight passing through Earth's atmosphere is slightly refracted, or bent, and partially fills in the shadow. Red light passes through large quantities of air more easily than blue light does, so the sunlight that reaches the totally-eclipsed Moon is predominantly red. (This is also why the Sun appears red when it's rising or setting.)

Two factors should cause this eclipse to be darker than normal. First, the apparent center of the Moon passes just 9′ from the center of Earth's shadow, which is approximately 90′ in diameter at the Moon's distance. Second, the Moon is less than two-and-a-half days from perigee, it closest approach to Earth this month, at the time of the eclipse. Thus the Moon is both deep inside Earth's shadow and nearly as close to Earth as it can be, which means less refracted sunlight will reach the Moon's surface than during a typical eclipse.

A third factor — one that can't be predicted — is the amount of sunlight that is blocked by clouds, dust, and debris injected into the atmosphere by volcanic eruptions. Major volcanic eruptions have a particularly powerful effect. The eruption spews large amounts of sulfur dioxide into the upper atmosphere, which mixes with the water vapor already present to form a mist of sulfuric acid. Although this mist causes only a 0.1- to 0.2-magnitude attenuation in starlight reaching Earth's surface, sunlight en route to the Moon during an eclipse passes through several hundred miles of this sulfuric acid and can be attenuated by five or more magnitudes!

This is what happened on December 30, 1963, and December 30, 1982. The total eclipses on those dates were preceded, respectively, by



MERCURY AND MARS appear in the same telescopic field on August 5. Mercury's position relative to Mars is shown at thirty minutes after sunset from four cities. The view is through an 8-inch f/10 telescope at 200x with south at the top.

the eruptions of the Indonesian volcano Gunung Agung and Mexico's El Chichon. During both eclipses the Moon nearly disappeared from view and appeared to the naked eye as little more than a 0.5° "hole" in the starry sky. No one knows yet what the Moon will look like during this month's eclipse, so observe the Moon's color and overall brightness closely at mid-totality.

Another interesting observation you can make with a low-power telescope is to time Earth's shadow as it enters and leaves various lunar craters. Choose ten to twenty craters and record their immersion into and emersion from Earth's shadow to within a tenth of a minute. Record the time for smaller craters when the crater is bisected by the edge of the umbral shadow. For large craters you should record the time when the shadow crosses each edge and average the two times.

Such measurements reveal an unexpected fact about Earth's shadow: it is slightly larger than the size predicted based solely on the geometry of the eclipse. The enlargement is caused by our atmosphere and varies from eclipse to eclipse, though is usually near 2 percent. A high-school student who has had trigonometry could use these shadow timings as the basis for a good science project that models the increase in size of Earth's shadow.

A CLOSE PLANETARY CONJUNCTION

Mercury and Mars pass less than 1′ from each other at 22 UT on August 5. This event occurs in the late afternoon for most North American observers, so you'll have to wait a few hours to see the close pair. Look for the planets close to the western horizon about thirty minutes after sunset. By then Mercury and Mars are a few arcminutes apart, but they still appear in the same telescopic field of view.

Mercury's disk measures 5.4″ across and is 83-percent lit, and Mars is fully lit and appears 3.6″ in diameter. Compare the surface brightnesses of the two planets. Mercury shines at a total magnitude of −0.4 and Mars at a total magnitude of 1.8. Because Mercury appears slightly larger than Mars, their average surface brightnesses are not quite so widely spread (magnitude 2.8 for Mercury compared with magnitude 4.3 for Mars).

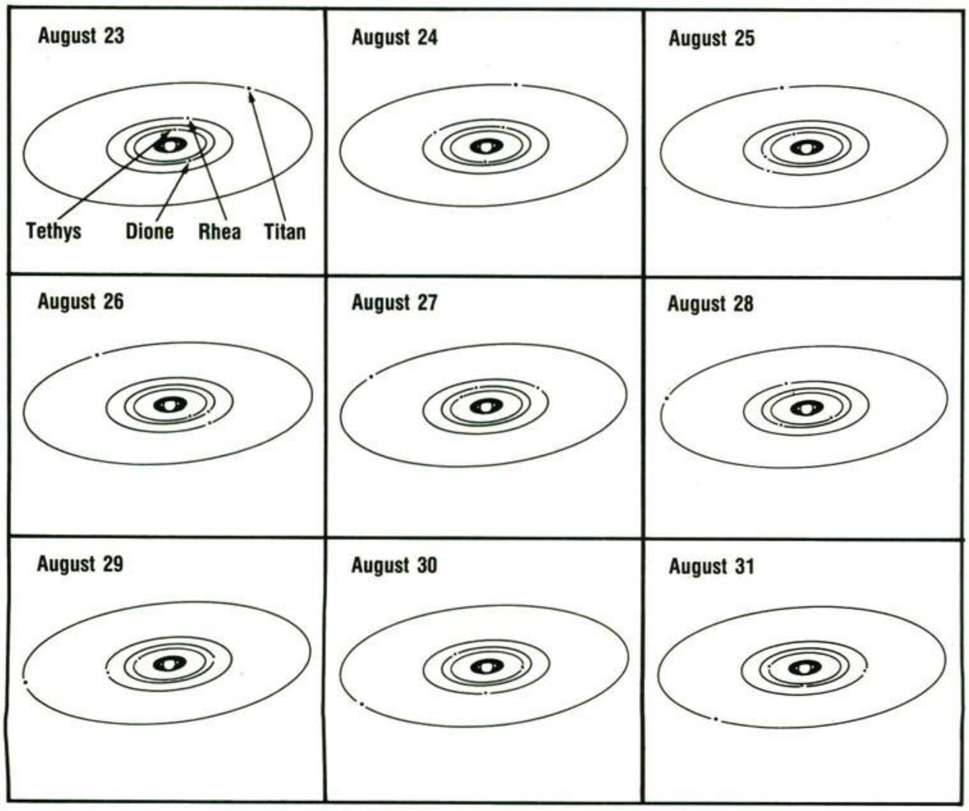
TELESCOPIC PLANETS

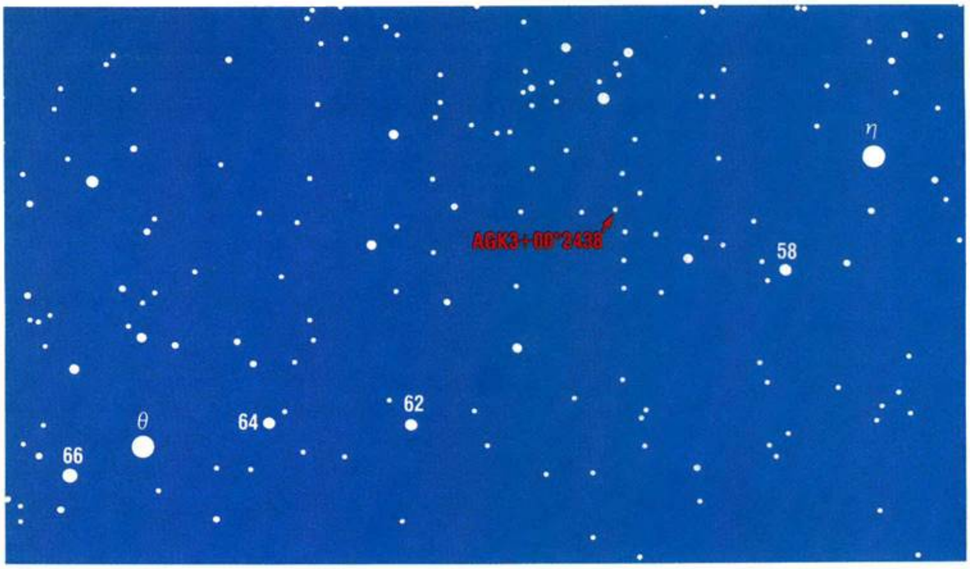
Mercury makes its worst apparition of the year in the evening sky this month. It lies 27° east of the Sun on August 29, but it is only 4° above the horizon thirty minutes after sunset. The close conjunction with Mars on August 5 is the highlight of Mercury's month.

Venus is low in the west just after sunset all month. Although it is conspicuous to the naked eye because it shines so brightly (at magnitude −4.0), Venus offers little to the telescope user because of its low altitude. This month Venus sports an 80-percent lit gibbous disk measuring 13″ in diameter.

As with Mercury, Mars' main event this month is the close conjunction on August 5. The Red Planet disappears into the sunset glow around the middle of August

THE SATELLITES OF SATURN are easy to spot if you know where to look for them. These drawings show the positions of the four prominent moons at 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT).





THE POSSIBLE BINARY ASTEROID Kleopatra occults the star AGK3 +00°2438 on the morning of August 14. The 9th-magnitude star lies less than 2° east-southeast of Eta (η) Aquilae.

and won't reappear until mid-November, when it will grace the morning sky.

Jupiter is now prominent in the hours before dawn. The giant planet rises in the northeast shortly after midnight by the end of the month and is high in the eastern sky as morning twilight begins. Jupiter's disk grows slightly larger this month, from 34″ to 36″ across, and you should be able to see some details on its surface. Use medium magnifications to look for the alternating bright zones and dark belts and the salmon-colored Great Red Spot.

The three outer gas giants remain close together and well-placed for observing this month. Saturn is easily the most interesting of the three. Its 18″-diameter disk may show one or two equatorial bands if the seeing is good, but the showpiece of Saturn is always its rings. Spanning 40″, the rings tip their northern face toward us this year. The easiest ring feature to spot is Cassini's division, which appears as a dark gap in the outer part of the rings. Astronomers used to think Cassini's division was devoid of material, but the *Voyager* spacecraft showed that it contains a number of thin rings.

Voyager 2 offers a good excuse to observe Neptune this month. The spacecraft makes its last planetary encounter, with Neptune, on the night of August 24/25. Although Neptune's blue-gray disk measures only 2″ across and glows dimly at 8th magnitude, take a few minutes to observe it as *Voyager* skims by the planet's north pole. Neptune is easy to find that night, located 2.5° east and 0.5° north of Saturn.

Uranus is a 6th-magnitude planet with a pale blue-green disk 3.7″ in diameter. This month Uranus lies 7° west and 1° south of Saturn.

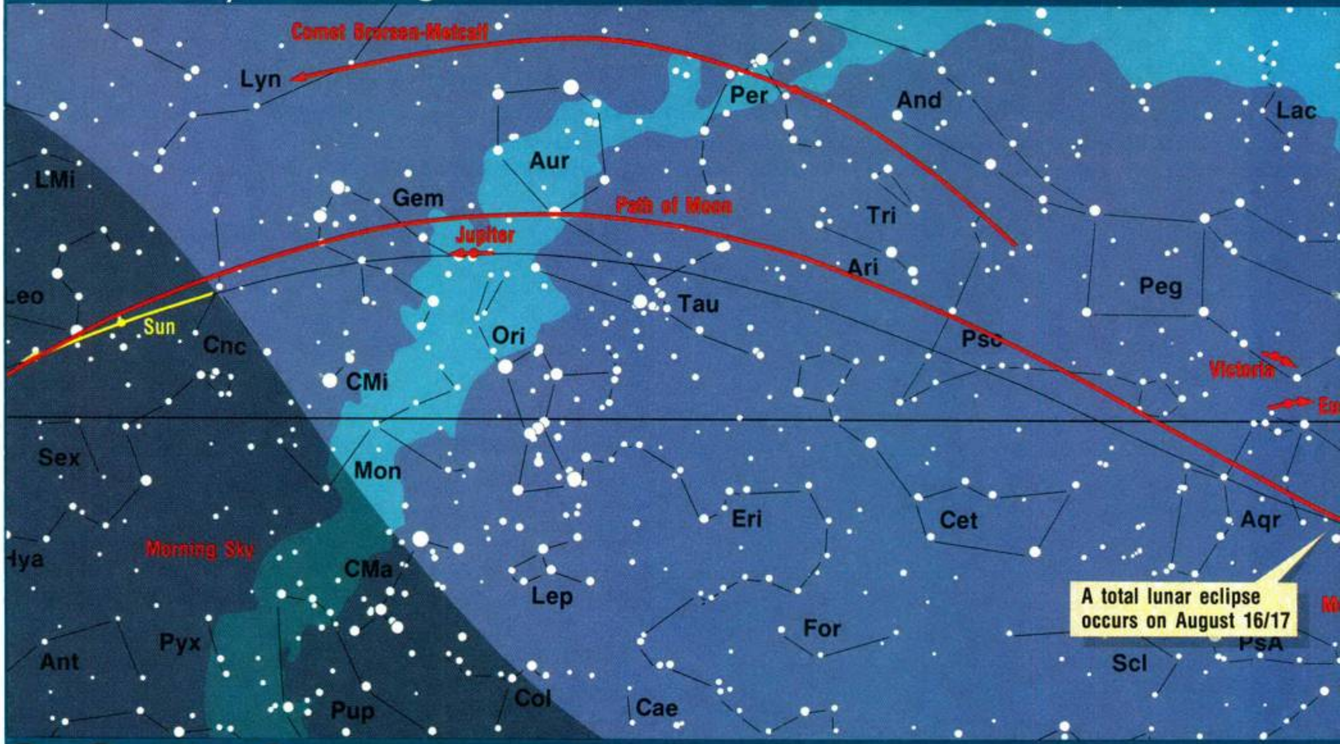
ASTEROIDS IN THE EYEPIECE

Several bright asteroids — Eunomia, Victoria, Metis, and Psyche — reach opposition this month, and Vesta remains a 6th-magnitude object through most of August. However, the most interesting asteroid observation you can make this month is of 216 Kleopatra, an unusual and possibly binary asteroid. On the night of August 13/14 Kleopatra occults the 9.1-magnitude star AGK3 +00°2438 for observers in the northwestern United States and western Canada. For observers in the remainder of North America, the 11.2-magnitude asteroid makes a very close approach to the star.

The event occurs at 7:39.3 UT on the 14th (3:39.3 a.m. EDT, 2:39.3 a.m. CDT, 1:39.3 a.m. MDT, and 12:39.3 a.m. PDT) and lasts up to twenty-four seconds. Use the finder chart above to identify the field at least a half an hour before the event. Then increase the magnification to 150x to 200x. This allows you to see both AGK3 +00°2438 and Kleopatra. You won't be able to perceive continuous motion, but you should notice the relative motion of the two objects.

Kleopatra is suspected to be either quite elongated in shape or a pair of closely orbiting asteroids in near contact. If you make accurate timings of the occultation, send the results to James Stamm of the International Occultation Timing Association (IOTA), 11781 North Joi Drive, Tucson, AZ 85737. If you fail to see an occultation, send those results anyway; it's just as important to know where Kleopatra's shadow did not fall as where it did! And finally, remember that predictions of such events are rarely ultra-accurate, so begin observing the pair early. □

The Solar System August 1989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Eri
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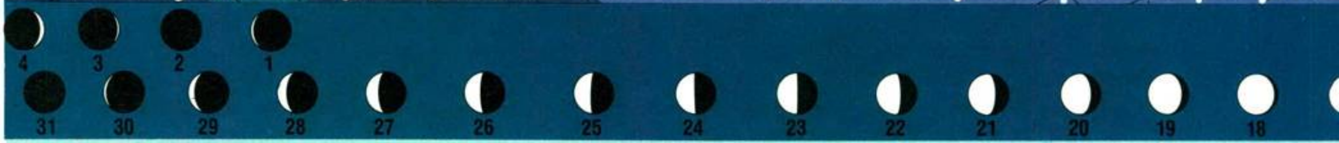
A total lunar eclipse occurs on August 16/17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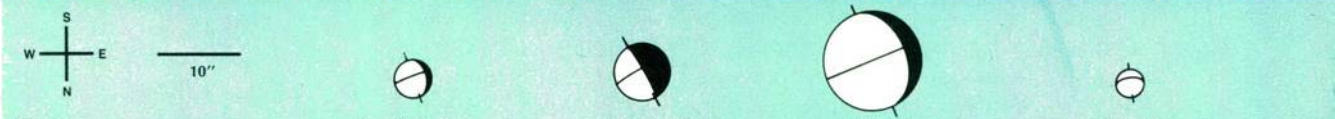
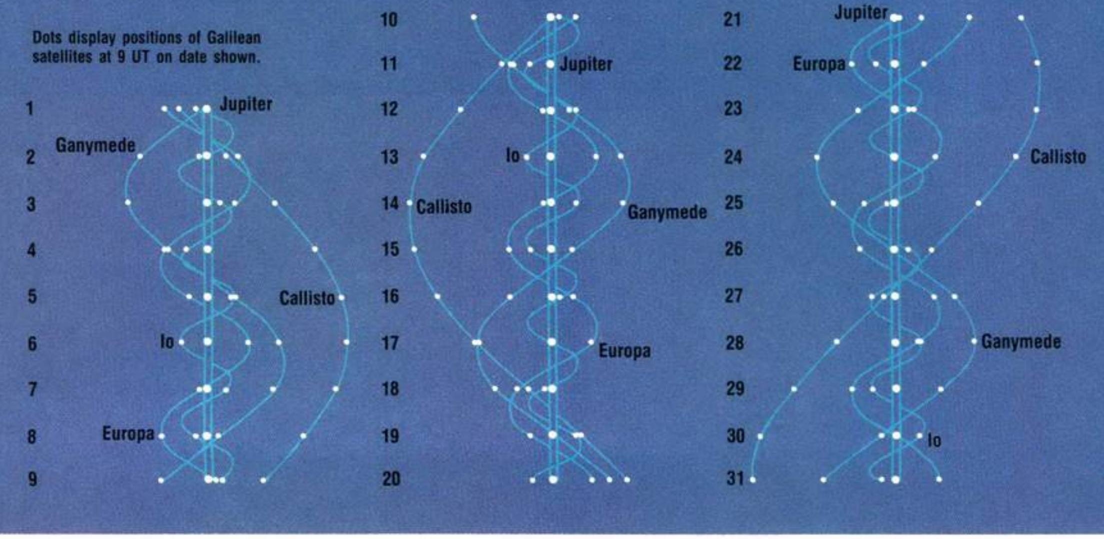
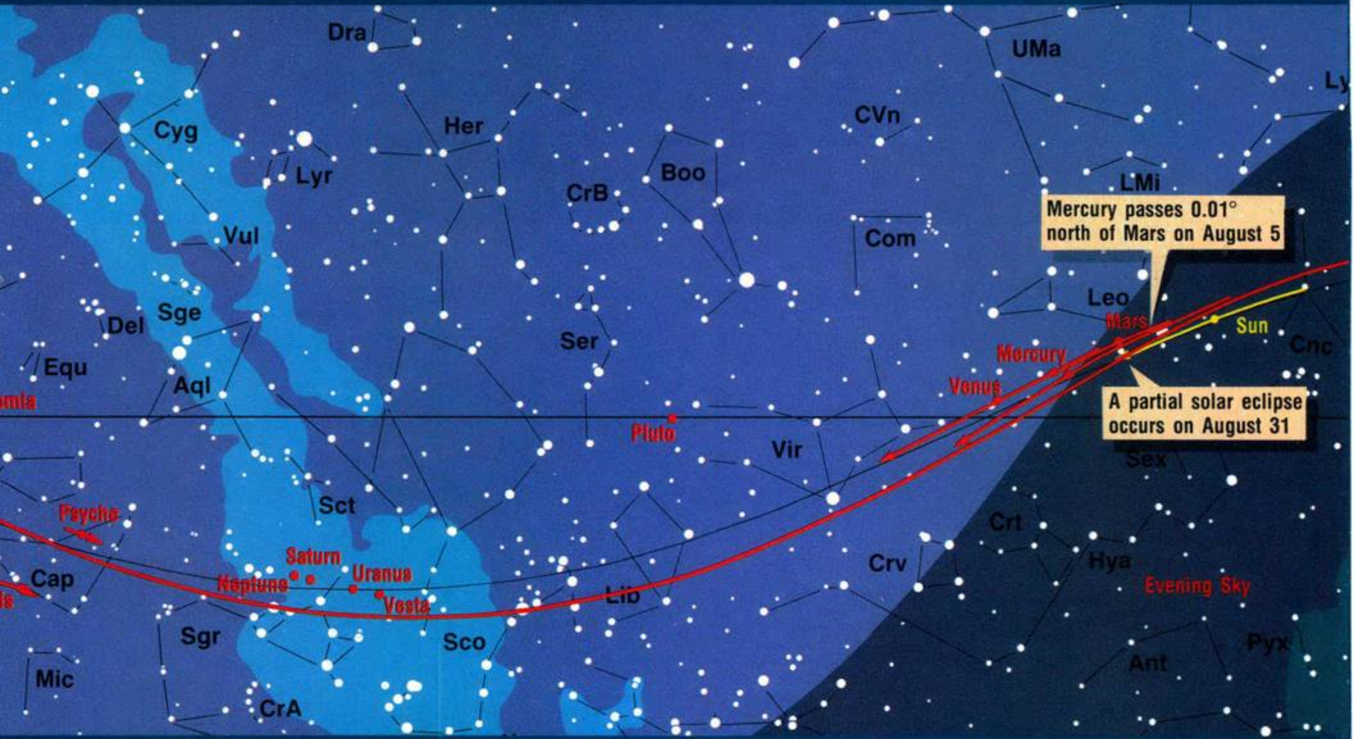


Planet	MERCURY	MERCURY	VENUS	MARS
Date	August 1	August 31	August 15	August 1
Magnitude	−0.7	+0.3	−4.0	+1.8
Angular Size	5.23″	7.40″	13.0″	3.6″
Illumination	89%	51%	81%	99%
Distance (AU) from Earth	1.285	0.909	1.285	2.586
Distance (AU) from Sun	0.392	0.462	0.724	1.666
Right Ascension (2000.0)	9h43.6m	12h13.7m	11h48.5m	10h04.3m
Declination (2000.0)	15°17′	−4°15′	2°14′	13°02′

Jupiter's Moons

Dots display positions of Galilean satellites at 9 UT on date shown.

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Psyche
Crt
Saturn
Uranus
Neptune
Vesta
Cap
Lib
Crv
Hya
Evening Sky
Sgr
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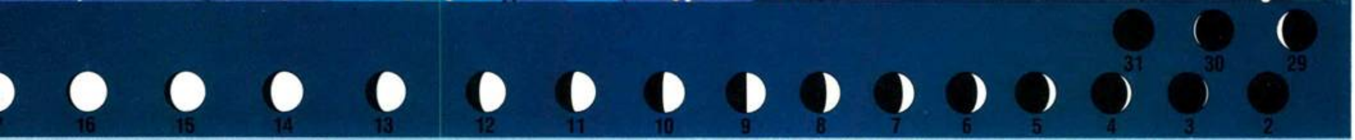
Pyx
CrA

Mercury passes 0.01° north of Mars on August 5

A partial solar eclipse occurs on August 31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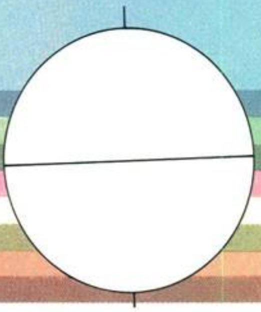
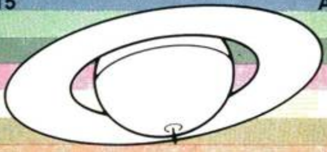
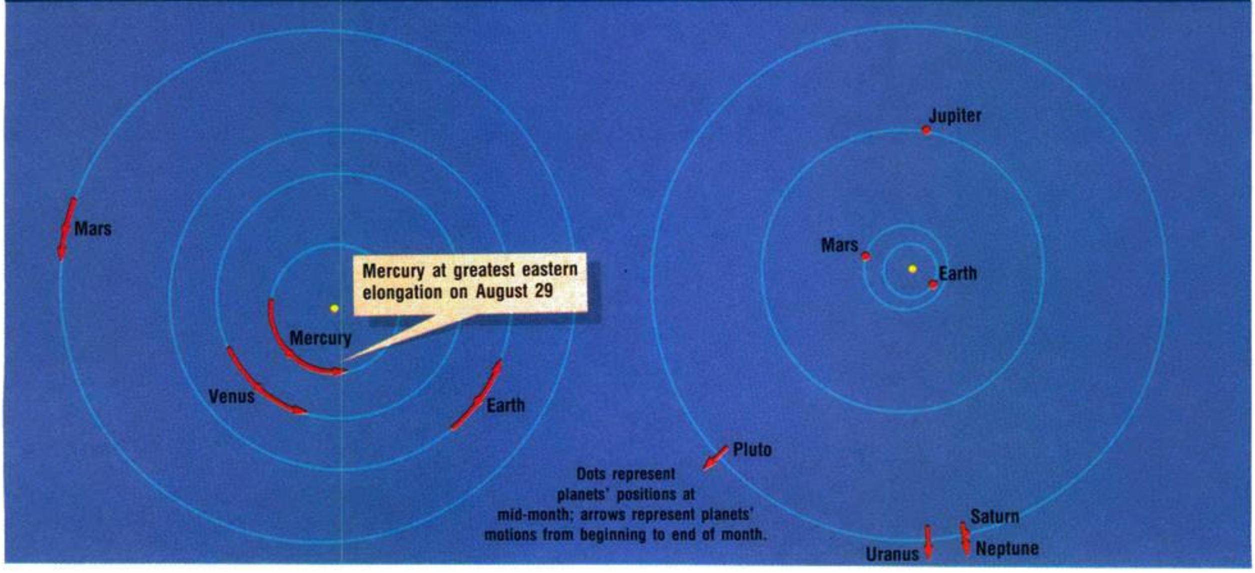




JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
August 15	August 15	August 15	August 15	August 15
−2.0	+0.2	+5.6	+7.9	+13.7
34.5″	17.8″	3.7″	2.3″	0.1″
99%	100%	100%	100%	100%
5.706	9.286	18.696	29.456	29.802
5.102	10.036	19.355	30.214	29.656
6h13.4m	18h34.8m	18h07.7m	18h43.7m	14h59.6m
23°05′	−22°39′	−23°42′	−22°08′	−0°43′

The Planets in Their Orbits


Mars
Mercury
Venus
Earth
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Mercury at greatest eastern elongation on August 29

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

Don't Forget the Bug

Be prepared for anything under the stars with these ten essential items. Don't leave home without them!

by David J. Eicher

1 Bring boots, a hat, and gloves.

Comfort is everything in backyard astronomy. If you're not warm enough, standing out under a star-filled sky is no fun at all. After the Sun goes down, temperatures drop rapidly. Make sure that when you go outside you cover your head — the area where half of the heat loss occurs — with a warm, lined hat that covers your ears. Wear gloves lined with wool or thinsulate and make sure your coat or jacket overlaps the gloves so wind can't reach your wrists. Wear two pairs of warm socks and boots that fully cover your ankles. Once you do this, you'll be ready for the chilliest summer night.

Several years ago I visited a friend in California's Mojave Desert and we observed deep-sky objects along the summer Milky Way long into the night. It had been over 100° F that day and so naturally I began scanning the evening sky wearing nothing but shorts, a T-shirt, and sneakers. The views were great, but by 4 a.m. I was nearly hypothermic, a casualty of the bone-chilling cold. The air temperature had dropped 60° in six hours. I don't think I stopped shaking for two days.

2 Pack snack food for quick energy.

Food is an essential part of any observing kit. When you begin observing in the early evening, eating is probably the furthest thing from your mind. However, observe for two or three hours and you'll probably reawaken your appetite. Even if you've worn the proper boots, hat, and gloves, you won't remain comfortable standing outside in the dark if you're hungry. Additionally, food can help revive you if you begin to run out of gas mentally.

Bring along a selection of snack foods that you like for the wee hours. Seal the food supply so the food doesn't dry out or critters don't taste it before you do. Foods with a high carbohydrate content give you a boost of energy quickly: try apples, breadsticks, candy bars, cookies, crackers, or granola bars.

The right drinks will also help keep you awake, alert, and warm. Most brands of soda contain a whopping dose of sugar (a water-soluble carbohydrate) and caffeine, which acts as a stimulant. Coffee and tea also contain caffeine and have the advantage of being served warm. A well-insulated thermos keeps drinks warm for several hours.

3 Make sure you're ready for bugs.

Nothing ruins summertime observing faster than a cloud of mosquitoes. It's difficult enough to soak up photons from distant galaxies without being pestered by a persistent swarm of biting or stinging insects.

The best protection against this menace is to keep a stock of effective bug spray or lotion handy. The strength and reliability of bug repellent varies greatly, so it's best to test out a brand before you really need it.

If you can, avoid bugs in the first place. Seek high-altitude, low-humidity ground away from fields, streams, or brush. This puts some distance between you and the favorite breeding grounds for mosquitoes and other pesky bugs. Don't worry about observing in a light breeze — it cuts down the insect air traffic. Most flying critters won't bother you the way they do on a night when the air is still.

4 Bring several red-filtered flashlights.

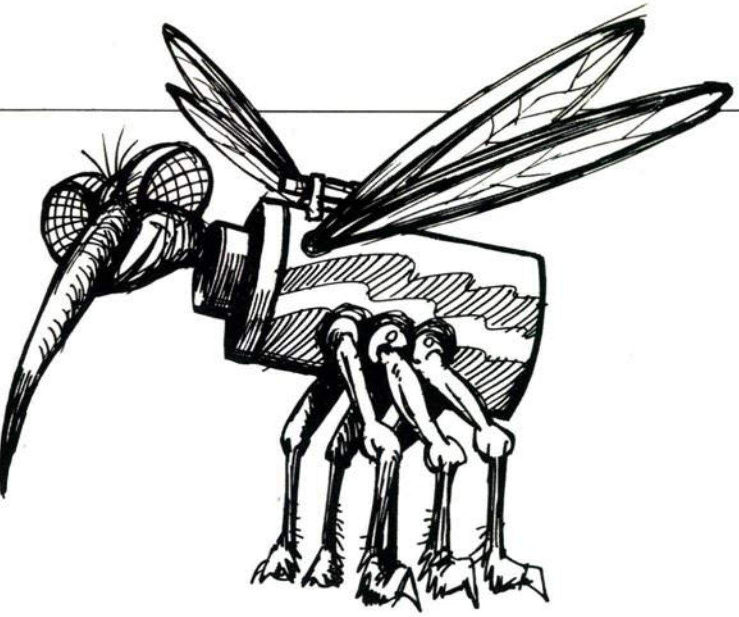
Take at least two small flashlights with relatively opaque red filters fitted on them and spare batteries on every observing trip. That way even if your batteries die or you misplace one light, you'll still be able to observe.

One of the greatest misconceptions in amateur astronomy is that pretty bright lights are okay to use for reading star charts, as long as they're covered with a red filter. True, your eye's faint-light receptors are not very sensitive to red light, but they become sensitive if there's enough of it. Make sure your lights are barely bright enough to read star maps — but no more. That way you won't disturb your dark adaption. Always treat your dark adaption as a precious commodity.

5 Carry an observing log — and use it.

Carry an observing notebook and jot down a record of the objects you look at and perhaps a few notes about their appearance. I wish I had a nickel for every time I've heard someone talk about the great cluster they saw in Cassiopeia *but they couldn't remember* which one because they didn't keep any records and a couple of weeks ago they forgot its catalog number. Your logbook could be a pocket memo book, a quarto-size three-ring

Spray!



notebook, or a folio-size art sketchbook. You can even dress it up by adding sketches or data on the objects culled from observing books.

After several months of keeping a log, you'll find yourself spending cloudy nights dipping back into the pages, reliving the sights and experiences you had and triggering memories of great observing sessions. Soon the observing log will be one of the most treasured books on your shelf.

6 Bring a folding table for accessories.

A folding card table serves nicely as a platform to hold accessories and spread out maps and charts on. Also, because you're bringing an observing logbook, a star atlas, food, and flashlights, you'll need somewhere to put all of this stuff.

By keeping accessories and food off the ground you'll help isolate them from ground moisture and crawling critters. Some clean rocks will keep maps and papers from blowing away. However, keeping books and atlases on a table isn't all you need to do to protect them from the elements. You also need to . . .

7 Protect star atlases and books from moisture.

The best way to protect paper goods is to unfold them, look at them briefly, then close them up. Star atlases and books are expensive items these days, and you certainly don't want to buy new copies every year. If you let paper goods sit exposed to the air for long periods, they'll absorb some water and eventually become crinkled and destroyed.

On really damp nights, some observers take out books and charts to check positions and then place them directly into an old briefcase or bag and zip it up. An alternative is to photocopy the pages you'll need and take the copies outside. That way you don't expose valuable, original books to the elements.

8 Keep a dew zapper handy at all times.

Because dew is present on practically any summer night — unless you're in a very dry climate — it's a good idea to take along a "dew zapper." Dew doesn't limit its effects only to paper goods. Excessive moisture in the air also fogs telescope optics and eyepieces and can become so obtrusive that you simply have to stop observing and go inside.

Several telescope suppliers sell dew zappers, which simply amount to an electric hair dryer. Some plug into a standard electrical outlet, while others have special adaptors that plug into auto cigarette lighters. A blast of hot air for a few seconds will defog the dampest eyepieces, mirrors, or corrector plates. Be careful not to overheat corrector plates, however, because they are made of thin, delicate glass that could crack if overheated.

9 Always have plastic garbage bags.

Summer weather can behave in a screwy fashion. On really damp nights, or if the weather changes in a hurry, you'll want protection for your valuable observing equipment. A sudden, unexpected downpour can ruin books, eyepieces, filters, and extension cords if you're caught helpless.

To prevent this, take along a box of plastic garbage bags. You can cover items with these bags and quickly limit the water damage. You can even use plastic bags as impromptu ponchos — that is, if you get the extra-large-sized ones.

10 Pack a portable radio or cassette player.

Hours spent under the sky can get pretty lonely — so bring company. If you're planning a late night observing session and you'll be alone, take along a portable radio or cassette player.

I'll never forget what happened one night in 1979. I was listening to the "Larry King Show" while wrapping up an observing session. After sketching galaxies for several hours and getting ready to tear down, the most brilliant, glaring fireball I've ever seen streaked overhead. It cut the sky in half and erupted at the end of its track, momentarily casting a shadow on the ground. It scared the heck out of me. After this scare, the end mark of a long, lonely session of staring out into the universe, it was comforting to hear the familiar chatter of human voices coming from the little radio on my card table. □

Meade & Celestron
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices. Both Catalogues $3.

LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

The "Flame Nebula" NGC 2024 in Orion. Also known as the "Christmas Tree" or the "Tank Trucks" nebula. NGC 2024 is seen best usually with either a LUMICON DEEP-SKY or UHC filter. Photo by Don N. Reiners, 16" f/5, 40 min. using hypered 2415 film and a LUMICON 2" EASY-GUIDER.

20mm NAGLER

Also new 12mm & 16mm NAGLERS TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK

Renaissance 4" f/5.5. Telescope	$1395
7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	**$89**
1.8X or 2.5X Tele Vue Barlow Lens	**$89**
32mm Plossl, widest true field in 1¼"	**$109**
55mm 2" Plossl, widest possible field	**$190**
15mm Wide-Field, 1¼" eyepiece, 65°	**$129**
19mm Wide-Field, 1¼" eyepiece, 85°	**$139**
24mm Wide-Field, "superb," 65°	**$159**
32mm Wide-Field, 2" eyepiece, 65°	**$229**
40mm Wide-Field, "awesome," 65°	**$289**
4.8mm Nagler, 82° field	**$149**
7mm Nagler, 1¼" eyepiece, 82° field	**$185**
9mm Nagler, 82° field, "the best"	**$219**
11mm Nagler, 82° field, 1¼" or 2"	**$235**
13mm Nagler, 82° field, 1¼" or 2"	**$249**
12mm Nagler, type II, 82°, 1¼"/2"	**$249**
16mm Nagler, Type II, 82°, 1¼"/2"	**$299**
20mm Nagler, Type II, 82°, 2" only	**$340**

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced silver diagonal mirrors & 1¼" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**
4.25"	**$149.50**				

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$89.50**
2" (1.83" mirror)(see photo above)	**$145.00**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission=90-97%.

"I CAN SEE THE OWL NEBULA!"
Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, *"I had never seen M-97. . . I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment."* **Tom Kramer, Sayville, NY**

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 85-95%.

	Standard	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces		$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$59.50	$79.50
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$99.50	$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$99.50	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces		$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces		$199.50
Set of Both premium **DEEP-SKY** and **UHC Filters** (Save 11%), Premium		$159.50
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. 1¼" **$99.50, 48mm**		$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines **1¼" $99.50, 48mm**		$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		$20.00

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.
LUMICON Adjust. Piggyback Mount .. $45
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$39.00**	**$34.00**
52, 55, 58, 62mm	**$49.00**	**$39.00**
67, 72, 77mm	**$59.00**	**$49.00**
82mm	**$69.00**	**N/A**
Hypered 2415 film, 36 exp	**$10.95**	**$3/$29**

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For phone orders please call (415) 447-9570
LUMICON Products catalogue $2.
Foreign orders add 6% ($8 minimum)
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DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.
U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**

MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent #4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$89.50**
Guider for Hasselblad **$350,** Mamiya 645	**$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER	**$225.00**
Adapter for Hasselblad **$185,** Mamiya 645	**$159**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645	**$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ± 12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) .. $70
NEW Deluxe Digital Qtz. Drive Correc. **$298**

NEW **SRV3200**

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SRV3200, fastest of all, color neg	24	**$13.95**
Konica SR3200, unhypered	24	**$8.50**
Konica SR400, fine grain color neg	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

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LUMICON® SKY VECTOR™- *NEW!*

Computer-Controlled Digital Setting Circles, only $498

Sky Vector ™
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STAR
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LUMICON SKY VECTOR™ computer, showing digital readout of coordinates, and easy-to-use controls. Shaft encoders are included (not shown). The coordinates are for Minkowski 1-79, a 13th mag. planetary nebula.

The LUMICON SKY VECTOR™ is a computer-controlled digital setting circle system. It represents a break-through in both computer performance and low price. To find an object just move the telescope until the coordinates of the SKY VECTOR™ match those of the object desired.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

Incredibly Smart!
thus
Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
- Digital decl. readout to 10 arc-min
- Digital altitude readout to 1°
- Motor drive ***not required!***
- Polar alignment ***not required!***
- Just sight two stars!

The computer's sophisticated program (over 3000 lines of code) determines **everything** from an initial sighting of just two stars!

- **No need** to enter latitude, longitude, sidereal time, date, etc.
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080. The computer automatically knows the difference.
- Uses Epoch 2000.0, 1975.0 or 1950.0 coordinates.
- Light weight, only 2 oz. permits mounting near the eyepiece, if desired. Only 2.6"x2.6"x1".
- 9V Battery lasts many nights.

LUMICON SKY VECTOR™ for Meade 2080,2120,C-8,C-11, *(Specify)*	**$498**
For Celestron-14 .. **$525.** For any alt-azimuth (Dobsonian) telescope	**$498**
For Coulter Odyssey 8", 10", 13", 17½" *(Specify telescope)*	**$498**
SKY VECTOR KIT. You must supply adapting hardware. For skilled ATM's only	**$449**

Reference catalogues listing coordinates of 1000's of objects

Burnham's *Celestial Handbook*, Vol. I, II, III (Epoch 1950.0)	**$36.85**
The *Revised New General Catalogue* (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II, doubles, variables, deep-sky objects	**$29.95**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

1.5x, 1.8x MULTIPLIER LENS

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. It multiplies by 1.5x without the included extension tube. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.5x/1.8x multiplier lens	**$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $49.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.

LUMICON 1¼" Helical Focuser	**$49.50**
LUMICON 2" Helical Focuser	**$59.50**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion low profile focuser	**$139.00**
3 handles (see photo) for non-rotat. focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

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LUMICON ACCESSORIES

2080/LX6 8" f/6	**$1899**
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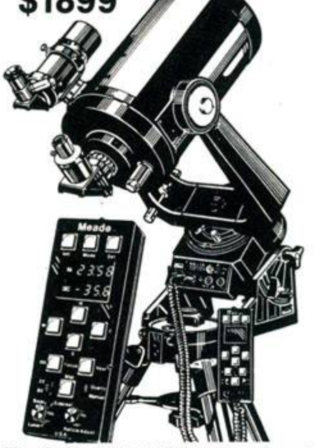
NEW 2080/LX6 $1899



Meade Model 2080/LX6: The most advanced Schmidt-Cassegrain telescope available today. The hand-held electronic command center controls all telescope functions, and has digital coordinate readout available as an option. The f/6.3 optics yield 2½x shorter exposures in astrophotography.

SCHMIDT-CASSEGRAIN

2080 Original 8" f/10 w/tripod	**$999**
2080/LX3, 8" f/10 w/MCOG	**$1389**
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2120/LX5, 10" f/10 w/MCOG	**$1995**
2120/LX3, 10" f/10 w/MCOG	**$1799**
2045/LX3 4" f/10 w/LX3 drive	**$795**
#39 declination motor for LX5	**$109**
#38 (LX3) or #38A (2045) dec. mtr.	**$99**
Dew shield - essential! 8" **$65;** 10"	**$98**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
MTS-SN8, 8" f/4 w/LX3 drive, MCOG	**$1048**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$975**
Model DS-10A, 10" f/4.5 w/mtr., 2" focus.	**$975**
Model DS-16A, 16" f/4.5 w/motor, 2" focuser	**$1975**
Model DS-16A w/Sealmaster ball bearings for photography	**$2195**
8X50mm finderscope w/brackets for DS-10,-16	**$109**

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89;** 32mm **$109**

Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**

Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

48mm COLORED GLASS FILTERS

These 48mm Filters thread into LUMICON EASY-GUIDERS and most 2" eyepieces. Use adapter for 1¼" eyepieces. AR Coated.

Filter:	**Bandpass**	**Trans**	**2"**	**1¼"**
Ultraviolet	320-420nm	85%	**$35**	—
UV Block	390nm-IR	98%	**$18**	—
Minus Violet	420nm-IR	96%	**$29**	**$18**
Blue Tricolor	340-470nm	80%	**$35**	**$18**
Hi Perf. Blue	300-540nm	95%	**$35**	—
Yellow	480nm-IR	98%	**$18**	**$18**
Green	490-590nm	60%	**$18**	**$18**
Orange	560nm-IR	98%	**$18**	**$18**
Red	600nm-IR	98%	**$18**	**$18**
H-Alpha Pass	640nm-IR	95%	**$35**	—
Cyan	340-580nm	95%	**$59**	**$29**
Adapter for 1¼" eyepieces				**$20**
Set of all 10 48mm filters ($340 list)				**$298**

EYEPIECE PROJECTION

These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

Tele-Extender for Meade or Celestron SCT.	**$32**
1¼" Basic Camera adapter, 2 part system	**$32**
0.96" Basic Camera adapter, 2 part system	**$32**
1¼" prime Focus adapter, fits 1¼" focuser	**$22**
0.96" prime Focus adapter, fits 0.96" focuser	**$22**
Camera T-ring, specify 35mm camera type	**$12**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle version, w/star diagonal	**$195**
2" right-angle version, non-rotating focuser*	**$199**
1¼" Deluxe right-angle Super-Finder*	**$279**
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2" Accessory adapter for Comet Catcher*, C-6*, Meade 310, 320 refractor	**$30.00**
2" adapter for Takahashi E-130, 160	**$59.50**

On the Trail of a Meteorite

Whether you hunt them, watch them fall from the sky, or collect them, meteorites let you make contact with a piece of another world.

by Christopher E. Spratt

It has been estimated that there is, on average, one meteorite for every square mile on the surface of this planet. And that number is constantly increasing as new meteorites continue to fall from the sky.

Yet despite their relative abundance, meteorites are very difficult to find, due in large part to their strong resemblance to ordinary terrestrial rocks. If you are an avid gardener, you may have handled a weathered meteorite at one time but tossed it aside as just another worthless rock.

Many meteorites have been recovered after initially passing unnoticed through human hands. Meteorites have been found in stone fences built by farmers after clearing a field. They have been discovered doing service as doorstops and weights for the lids of canning jars and rain barrels. Some very large iron meteorites have even been used as anvils.

On October 30, 1983, two treasure hunters, who were searching with metal detectors for Spanish armor at an ancient Indian refuse site near Grayton Beach, Florida, found a 24-pound stony meteorite under three feet of sand. Fortunately, they had enough presence of mind to submit their find for evaluation.

Actively searching for meteorites is a beguiling pursuit. Because meteorites fall randomly from space and have done so for a very long time, they could literally be found anywhere. This possibility has lured amateur meteorite hunters (including myself) to spend hours looking for meteorites. Sometimes these searches have been successful, but more often than not our quarry has eluded us.

What drives meteorite hunters to continue their quest, despite the long odds, is a desire that goes beyond the challenge of finding a rare and valuable object. Prospecting for gold is certainly more profitable, but it can't give you what a meteorite can: the chance to actually touch a piece of another world.

"Meteorites are tantalizing gifts of new information about the solar system, just waiting to be unwrapped," writes Harry Y. McSween, Jr., in his recent book, *Meteorites and Their Parent Planets*. They are pieces of the solar system that have been brought to Earth from distant objects such as Mars, the Moon, comets, and asteroids. As a group they provide unique information about our solar system that scientists are still trying to understand.

Chunks of Iron and Stone

The many different types of meteorites are classified by their mineralogical and chemical composition into three main categories: stony, stony-irons, and irons. Stony types are the most common, yet paradoxically, are also one of the hardest to recognize. They contain silicates as do terrestrial rocks, but in different proportions; some also contain high amounts of carbonlike materials. Stony-irons, the rarest type of meteorite, contain crystals of rock embedded in metal, or rock and metal more or less blended together. The irons are composed almost entirely of iron and nickel.

The odds that you will find a specific type of meteorite are largely determined by what the meteorite is made of. Iron meteorites are much more resistant to weathering than stony ones and consequently make up a larger percentage of meteorite "finds." After a few years, few stony meteorites are distinguishable from terrestrial rocks, especially to a casual observer. However, the majority of meteorites that have been found soon after falling to Earth — meteorite "falls" — have been stony.

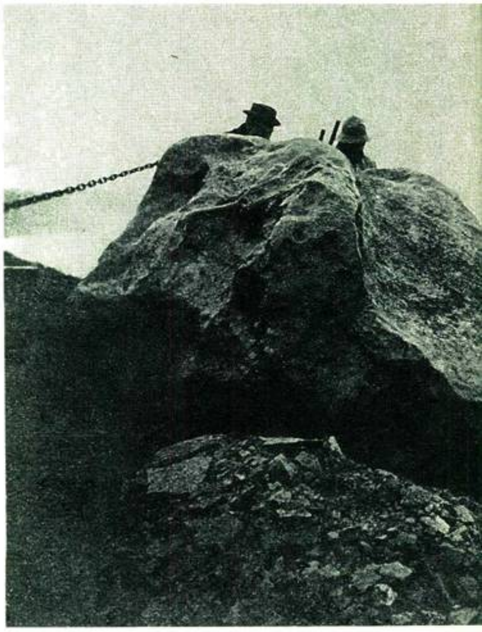
Each type of meteorite reveals a different history in its unique compositional features. The spherical, partially crystallized droplets found in one type of stony meteorites (chondrites) probably condensed from the gaseous solar nebula that formed the planets. In some meteorites these droplets are whole, while in others they have been shattered by subsequent impacts.

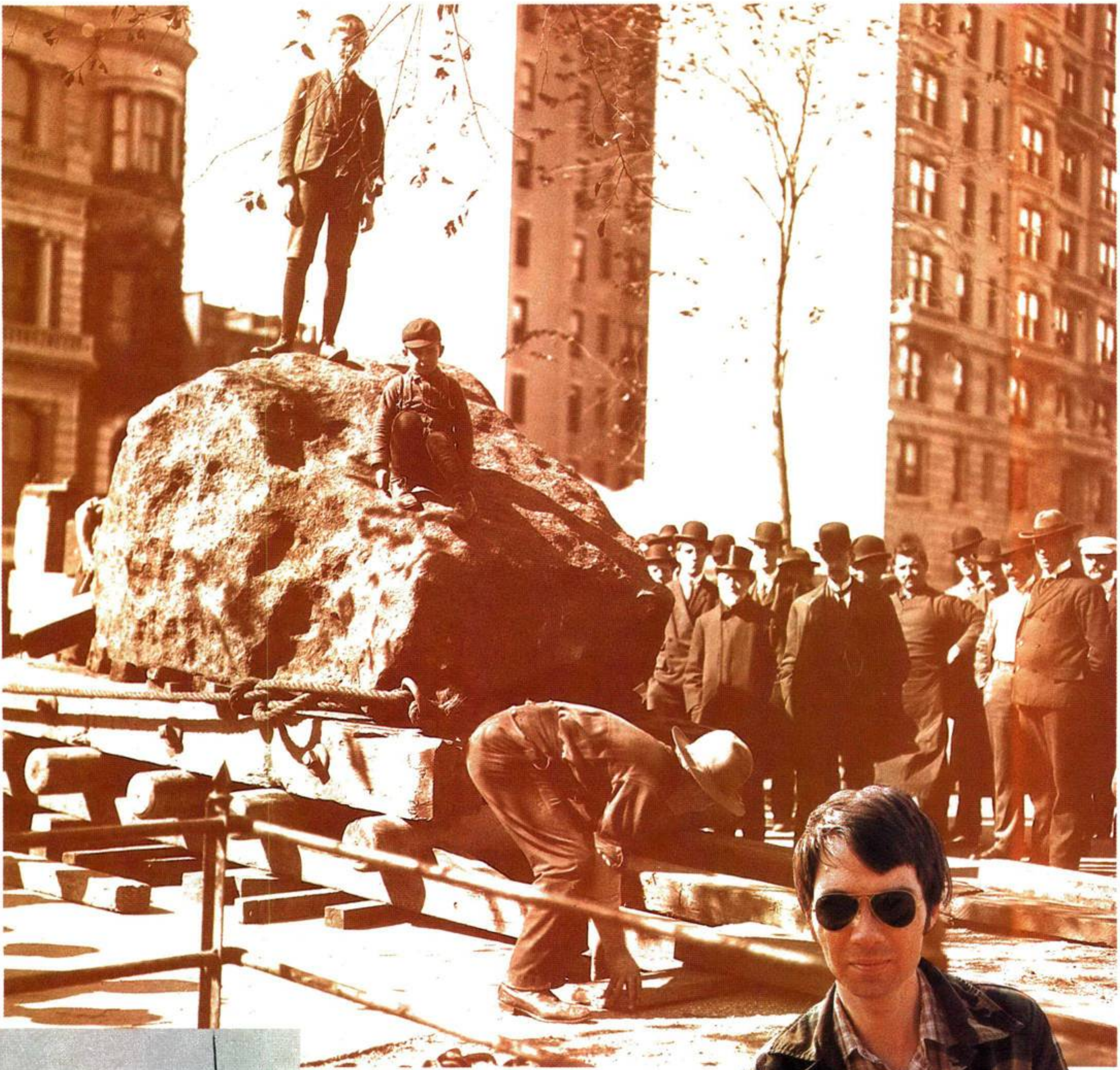
Carbonaceous chondrites, another type of stony meteorite, are rich in carbon interspersed with organic molecules. These are the most interesting of all the chondrites because many complex amino acids and primitive diamonds have been found in recently fallen samples.

The achondrites, another type of stony meteorite, have a coarsely crystalline structure very similar to terrestrial rocks such as basalts. Being igneous rock and often showing signs of impact events, achondrites were probably formed at or near the surface of the small planetary bodies that make up the asteroid belt.

Fragments of a Planet's Core

Iron meteorites are composed of metallic nickel-iron alloy minerals.





ESKIMOS MADE WEAPONS and tools from pieces of the Ahnighito iron meteorite in Greenland before Lieutenant Robert E. Peary unearthed it (left) and shipped it to New York City in 1897. The 59-ton meteorite, the largest currently on display in a museum, resides in New York's American Museum of Natural History. Modern-day meteorite hunters like John Martin of the Oklahoma Meteorite Laboratory (right) use metal detectors to search for more modest-sized samples of these extraterrestrial visitors.

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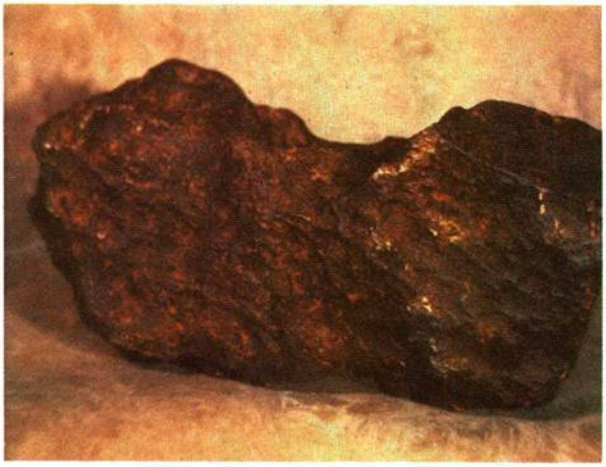
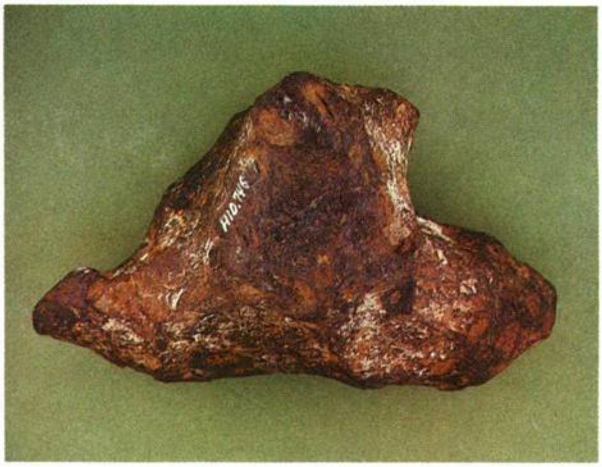
A Field Guide to Meteorites

Iron (Siderites)

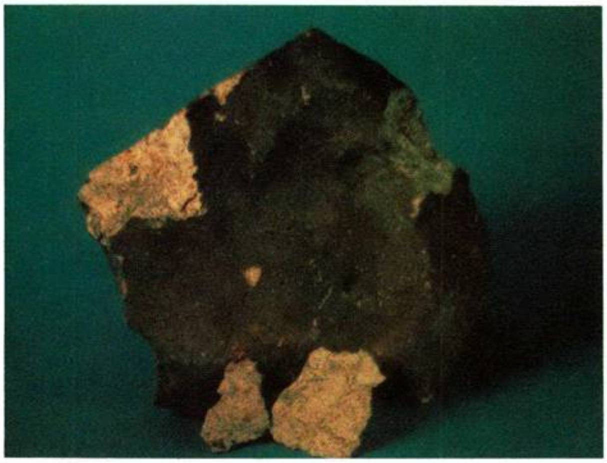


WATERVILLE, Washington, anomalous iron. Found 1927.

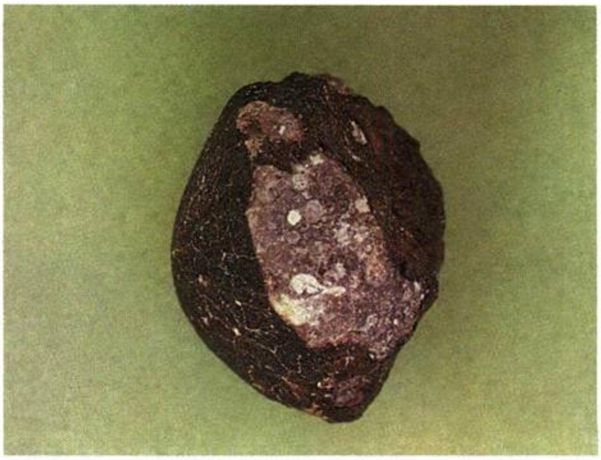


ODESSA, Texas, coarse octahedrite. Found 1922.

Stony (Aerolites)

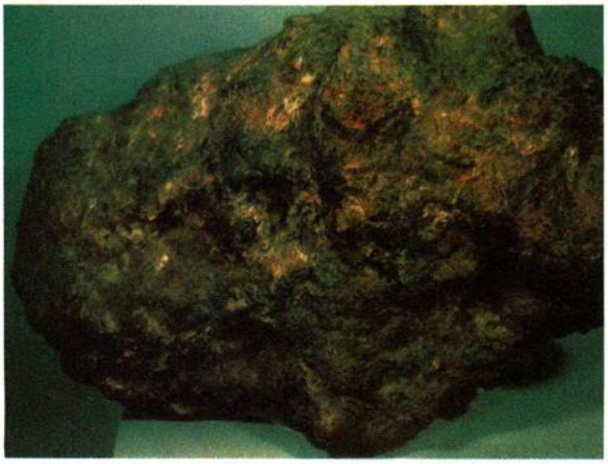


INNISFREE, Alberta, Canada, chondrite. Fell February 1977.

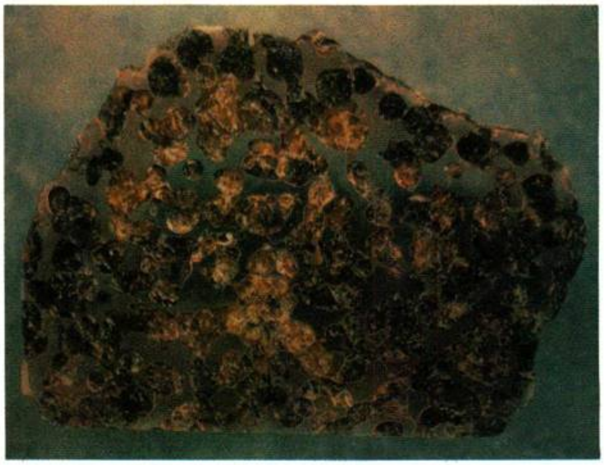


ALLENDE, Mexico, carbonaceous chondrite. Fell February 1969.

Stony-Iron (Siderolites)



BRENHAM, Kiowa County, Kansas, pallasite. Found 1882.



BRENHAM, Kiowa County, Kansas, pallasite. Polished slice.

They are black, shiny metallic masses with a warty surface and are usually magnetic. Iron meteorites are especially prone to rust even when carefully prepared and stored. Some iron meteorites may represent materials that condensed directly from the gaseous solar nebula. Others are probably the result of a planetary differentiation process, whereby heavy elements such as iron sink to the core of the parent body.

Stony-irons are composed more or less equally of silicates and the metallic iron-nickel alloys, along with traces of other minerals. Pallasites are the most abundant of the stony-iron types, and by far the prettiest meteorites. They contain crystals of a greenish silicate mineral, olivine, embedded in a matrix of nickel-iron. When cut and polished, pallasites show a beautiful structure. Pallasites are believed to have formed deep within a parent body in the region between the core and the mantle.

Although their composition gives definitive clues to their extraterrestrial origin, there is very little about the size and shape of meteorites that definitively distinguishes them from the average terrestrial rock. Meteorites may be any shape, except possibly perfectly spherical. Many meteorites have a symmetrical pattern of flight markings or ablation pits that appear to radiate from a point or a general area.

Meteorites vary considerably in size, from fine dust to objects weighing several tons. Most of the recent finds have been about 10 to 20 pounds; the really large meteorites are very rare. The carbonaceous chondrite Allende fall in 1969 spread over two tons of material over a large area in Mexico. The Sikhote-Alin dropped 23 tons over the Soviet Union, but not all in one place.

A meteorite frequently breaks up as it falls through the atmosphere, causing a shower of meteorite fragments over a specific geographical area called a strewn field, which is usually elliptical in shape. You can improve your chances of conducting a successful search by remembering that old strewn fields can yield new specimens long after the area was thought to have been thoroughly worked over. Some of the best areas to search for meteorites are the older sites of known meteorite falls or finds.

The American Midwest and the desert regions of Australia, Mexico, and Chile are prime regions for meteorite searching. It is no coincidence that most of the meteorite finds in the United States have been recovered from the rock-free soil of the arid western plains. Three states — Kansas, Texas, and New Mexico — account for the most finds of anywhere in North America.

In recent years a particularly good locale for finding new meteorites has been the ice-fields of Antarctica, where the dry, very cold environment has helped to preserve meteorites in an almost pristine condition. As the glaciers evaporate and the wind erodes the snow and ice, meteorites that fell thousands or millions of years ago are uncovered. Several thousand meteorites have been recovered in the last decade by both Japanese and American scientists. Some of these new meteorites are believed to have come from the Moon and, in one or two cases, Mars.

Trying to find a meteorite in the field demands knowledge and perseverance. Before you begin, you should be aware of your chances of finding a meteorite. About twenty-five new meteorites are turned up each year, most of which are finds. Out of an estimated 3,500 meteorites that strike the planet each year, about six recently fallen meteorites will be

Owning a Piece of the Universe

Canadian meteorites from the author's collection.

For about $50 you can own a half-pound chunk of the meteorite that blasted Meteor Crater out of the Arizona desert tens of thousands of years ago. A mere half-ounce fragment of the carbonaceous chondrite that fell in 1969 in Murchison, Australia, however, will set you back $240.

Like any other collectable item, the value of meteorites depends on a mix of objective and subjective factors. The rarity of a particular type of meteorite is the fundamental factor determining its value, but aesthetic judgments on shape and surface features also enter into the equation.

Meteorites can be purchased either as whole specimens, exactly as they were found, or as slices, thin sections cut from a larger original that have been polished to show intricate internal structure. Dealers carry a range of sizes, from less than an ounce to several pounds. Each meteorite comes with information on where it was found and a description of its composition.

Iron meteorites are in general less expensive than other types, averaging under $25 per ounce; stony-irons, the rarest type of meteorite, are the most expensive, commanding as much as $100 an ounce. The price of stony meteorites ranges between the extremes set by irons and stony-irons.

Meteorite dealers will provide catalogs and price lists upon request. Three dealers you might want to try are David New, P.O. Box 278, Anacortes, Washington 98221; Oklahoma Meteorite Laboratory, P.O. Box 1923, Stillwater, Oklahoma 74076; and Bethany Trading Company, P.O. Box 3726, New Haven, Connecticut 06525. — *Stephen Cole*

Stalking the Elusive Meteorite

Recovery of the Innisfree, Alberta, meteorite fall in 1977.

Meteorite hunters must dream about having Hewlett Hodges' luck. On November 30, 1954, as Mrs. Hodges dozed on a couch in her home in Sylacauga, Alabama, an 8-pound meteorite literally came to her, crashing through the roof and striking her on the hip.

Veteran meteorite hunters would be glad to trade Mrs. Hodges' bruises for the hours they have spent searching for meteorites. Compared to finding a rock-sized meteorite somewhere on the surface of the planet, locating the proverbial needle in a haystack would be child's play.

In 1986 five Canadian meteorite hunters searched a farmer's field in Mayerthorpe, Alberta, that had previously yielded several meteorites. Discovering that no systematic search of the field had ever been made, the group set out with metal detectors to see what they could find. After sixty man-hours of searching they had found three dozen nails, a dozen pieces of wire, but no meteorites. Undaunted, group member Peter Brown of Fort McMurray, Alberta, commented that despite their unsuccessful search, "the Mayerthorpe meteorite file is open to future reference and future searches might still prove fruitful."

To improve their chances, meteorite hunters frequently conduct searches where new meteorites are suspected to have fallen. Using visual sightings of bright meteors, or fireballs, as they burn through the atmosphere, a reasonably accurate location of the resulting meteorite fall can sometimes be determined.

One such fireball photographed over Canada in 1977 led to the discovery of a meteorite (photo above) in Innisfree, Alberta, just eleven days after the fireball was recorded. Another fireball in Alberta in March 1985 produced a number of visual sightings and an estimated fall area but no meteorites.

Meteorite hunters interested in keeping abreast of the latest fireball sightings and the activities of other hunters should subscribe to *Meteor News,* a ten-page newsletter published four times a year. To subscribe, send $3.95 ($5.00 in Canada) to *Meteor News,* Route 3, Box 1062, Callahan, FL 32011. — *S.C.*

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recovered annually.

Recognizing a Meteorite

Before embarking on a meteorite hunting expedition, you should have a good idea of what meteorites look like. One of the best ways to learn to recognize meteorites is to visit a museum or university that has a good collection and study them. Major collections can be found in museums in New York, Chicago, and Washington, D.C., and at universities such as Harvard, Yale, the University of New Mexico, and Arizona State University. Note carefully the morphologies and colors of the finds, especially the stony types.

If there are no collections near you, you might want to consider starting your own by purchasing one or two samples of each type from meteorite dealers. (See the box on page 73.) Lacking a good museum collection within easy driving distance, I started my own reference collection. (Meteorites may be expensive, but they always make good conversation pieces.) The more you look at meteorites, the better the chance you will recognize one if you come across it out in the field.

Generally, a close and careful inspection is required to differentiate a meteorite from an ordinary rock. A few field clues are helpful to keep in mind when trying to decide if a certain rock is a meteorite. Meteorites are usually dark in color. If it is a very recent fall, it will have a black fusion crust; if an old fall, the exterior will be brown from rust, which can make it look very similar to local rocks.

Meteorites are usually very dense and thus feel heavier than an average rock of the same size. Any rock heavier than those in the surrounding area should be considered a possible meteorite until laboratory tests prove otherwise.

Most meteorites are very magnetic, even the stony types. (An exception are the carbonaceous chondrites.) Few terrestrial rocks are magnetic. If there is some metal present, a magnet will cling to the rock; minor amounts of metal can be detected by hanging a magnet on a string and watching to see if the suspected meteorite attracts the magnet. Another simple test is to use a compass to see if the needle is deflected. Of course, manmade metallic iron or iron ore also attracts a magnet, so additional tests are required before a positive meteorite identification can be made.

Meteorites are not porous and do not contain bubbles or appear to have a "frothy" texture. Few meteorites have sharp edges, especially if they are at all weathered. The surface on many meteorites shows distinctive depressions or pits that have the appearance of thumb prints. These pits are generally oval or elliptical, usually with one rim more raised than the others. Unless weathering has occurred, the interior of these pits are lined with fusion crust.

A Meteorite Excursion

When undertaking a meteorite hunting trip, remember to go in the spirit of adventure and don't forget to bring along your common sense. Always leave word where you are going and when you expect to be back. If you have an accident or get lost, you will have some comfort in knowing that help will eventually come. A good topographical map of the area is essential. Also bring along a compass, waterproof matches, a knife, a folding shovel, a whistle for signaling, and a first-aid kit. Be alert for spiders, ticks, and poisonous snakes.

You should be courteous to and thoughtful of the owners of the land you are on at all times. Make sure that all gates are left exactly as you found them, open or closed. Don't forget that the owner of the land is legally the owner of any meteorites you find. (On state-owned property, the state is the legal owner.) It is essential, therefore, to obtain permission before beginning a meteorite hunt on private property. You may be required to sign a waiver to relieve the owner of responsibility if you get hurt on his property. Be sure to stick to all the terms of the permission when embarking on private property.

A good place to look for meteorites is in a farmer's rock pile. Here all the rocks from his fields have been gathered into one spot. Try not to throw rocks all over the place during your search; the farmer took the time to place them there so don't undo his hard work. An old ravine alongside a cultivated field is another good place to search.

Whenever possible, take a camera and a lot of film along in case you find a fall that has produced a small impact crater. If you are reasonably certain of a positive field identification, get all the details of the find: the exact date and time, location, size of hole or crater (if any), type of surrounding material (soil, gravel, rock), and the probable angle of descent.

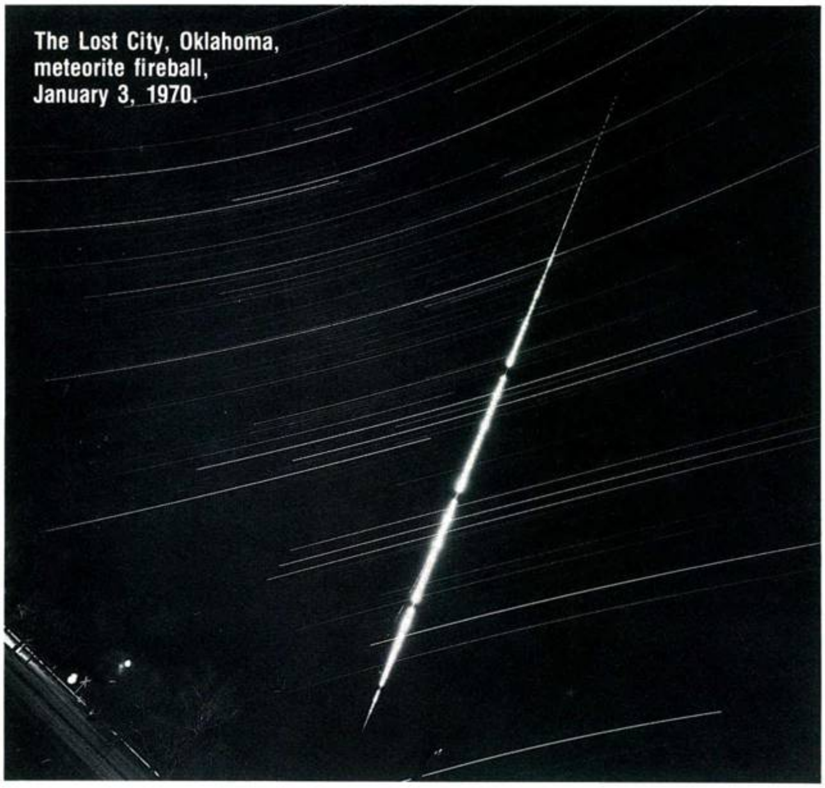
Excavate on one side of the meteorite with a shovel, being careful not to disturb the meteorite itself. When this is properly done, the meteorite will be shown resting quite naturally in the impact hole it has made. The idea is to record how far beneath the soil the meteorite is and in what manner the soil was disturbed by our celestial visitor. Finally, and most important, try to keep the meteorite intact until it has been examined by experts.

How to Test Your Find

Once you and your suspected meteorite are safely back home, there are several simple tests you can conduct. First, measure the density of your find. With rare exceptions, meteorites have a density of at least 3.3 times that of water (1 gram per cubic centimeter). Those rare terrestrial rocks exceeding this value are usually iron ores such as magnetite and hematite. However, other rocks can also be as heavy or even heavier than the stony meteorites.

A simple test for measuring density involves weighing your find with a spring balance scale, available at scientific supply stores for less than $10. Using a lightweight string or wire, attach the rock to the scale and record its weight. Next suspend it in water and record that weight. Subtract the second measurement from the first and you have a number that represents the total volume of your find. Divide the free-hanging weight by its

From Meteor to Meteorite



The Lost City, Oklahoma, meteorite fireball, January 3, 1970.

On the evening of Saturday, January 3, 1970, an extremely bright meteor streaked across the skies of Oklahoma. The event was quietly photographed by an automatic camera set up by the Smithsonian Astrophysical Observatory, one of sixteen cameras spread across the American Midwest to record just such events. The purpose of the camera network was to locate newly fallen meteorites by recording the trail they make as they blaze through the sky.

Analysis of fireball trail photos can produce reasonably accurate estimates of the location of any resulting meteorite fall. In the case of the 1970 Oklahoma fireball, a 22-pound stony meteorite was recovered just six days later.

Although this camera network and another in Canada have been shut down — evidence of the long odds of finding a meteorite even after successfully recording its fireball — visual reports of fireballs are still used to hunt for fresh meteorite falls. The Smithsonian Institution's Scientific Event Alert Network (SEAN) collects fireball reports from around the world and publishes them each month.

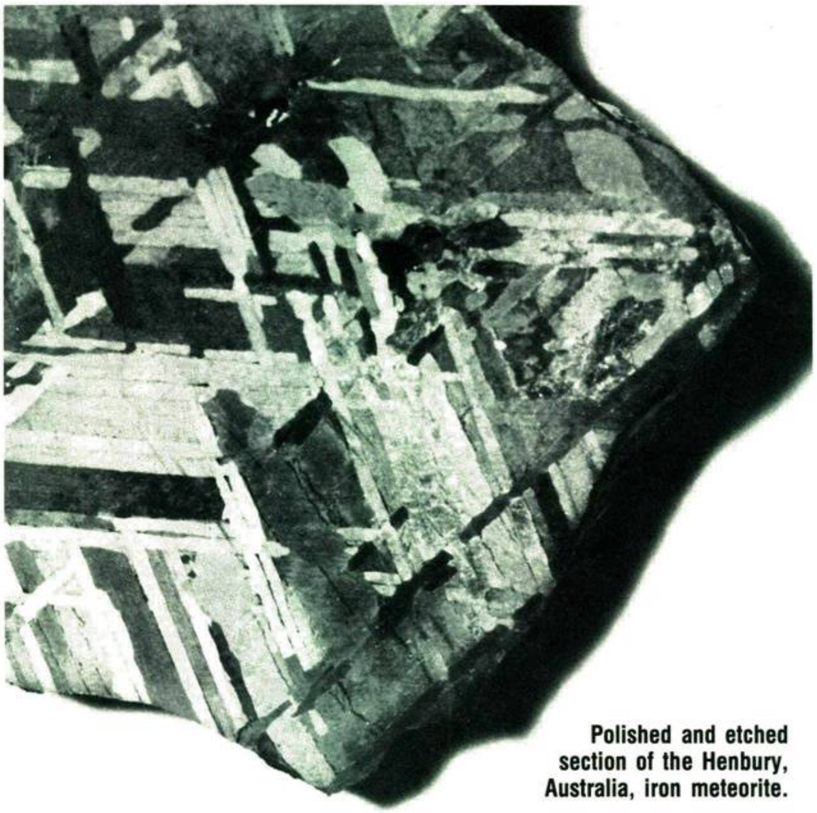
"Our primary interest in fireball reports is to find recently fallen meteorites," says SEAN's Lindsay McClelland. Working with a network of regional contacts, frequently planetarium directors and members of astronomy clubs, SEAN reports an average of ten fireballs a month.

Witnessing a fireball is not an experience you're likely to forget. Shining as bright as the Full Moon and often casting shadows, fireballs are occasionally accompanied by thunderous explosions. They sometimes explode and break up into several pieces, in which case the fireball is classified as a bolide.

If you are fortunate enough to witness a fireball, record your observation on a piece of paper, noting the time, the direction the fireball was traveling, and the point in the sky where it disappeared, using a distant landmark on the horizon for reference. With enough eyewitness reports, the estimated location of any meteorite fall can be calculated.

A fireball report form is available from SEAN, but McClelland recommends that anyone seeing a fireball first contact a local planetarium or astronomy club. Report forms are available by writing to the Scientific Event Alert Network, Mail Stop 129, Natural History Building, Smithsonian Institution, Washington, D.C. 20560. The monthly SEAN Bulletin, which also publishes notices of worldwide volcanic activity, is available for $18 a year. Subscriptions can be ordered from the American Geophysical Union, Fulfillment Department, 2000 Florida Avenue, NW, Washington, D.C. 20009. — *S.C.*

Is It Really a Meteorite?



Polished and etched section of the Henbury, Australia, iron meteorite.

If you have found a rock that you suspect is a meteorite, you might want to send it to a testing laboratory to confirm your suspicions. Before putting your sample in the mail, however, many laboratories recommend that you write to them first describing your find.

Arizona: Center for Meteorite Studies, Dr. Carleton B. Moore, Director, Arizona State University, Tempe, AZ 85287-2504. No charge for testing; brochure on identification also available.

Illinois: Field Museum, Geology Department, Roosevelt Road and Lake Shore Drive, Chicago, IL 60605; phone (312) 922-9410. Call for an appointment.

New York: The American Museum of Natural History, Mineral Sciences Department, Central Park West at 79th Street, New York, NY 10024. Write before sending sample.

Oklahoma: Oklahoma Meteorite Laboratory, P.O. Box 1923, Stillwater, Oklahoma 74076. No charge but include return postage; all samples returned.

Washington, D.C.: Department of Meteorites NHB119, Smithsonian Institution, 14th and Constitution Avenue, NW, Washington, D.C. 20560. Send description of how sample was found with sample; sample returned if requested.

Canada: Meteorite Identification, Geological Survey, 601 Booth Street, Ottawa, Ontario, Canada K1A OE8.

Australia: Western Australian Museum, Perth, Western Australia 6000.

England: British Museum of Natural History, Cromwell Road, South Kensington, London, England SW7 5BD.

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volume and you have the density of the object relative to the density of water.

If your suspected meteorite passes the density and magnetic test, next grind a small area of it with an emery wheel or a piece of emery paper. Stony meteorites will show shiny flecks of bright metal, and they often have veins running through them.

Be careful not to confuse these true metallic grains with certain other glittering crystals or flecks of terrestrial minerals such as mica or quartz. Experience and a good 10x hand lens will usually enable you to detect the difference, especially if you view your specimen from several different lighting angles. You can also probe one of the metallic grains with a sharp needle to see whether it crumbles. Nickel-iron will not crumble when treated this way.

If your find passes all these tests, submit a sample of your find to the nearest meteorite identification laboratory. (See the box at left.) Small samples should be sent intact; with larger finds submit a walnut-sized portion. Remember, some stony type meteorites are very fragile and will, if a fresh fall, disintegrate rapidly.

There is no charge for this service, and the sample will usually be returned. If your find is an authentic meteorite, the laboratory will usually make you an offer to purchase it. Their offer may be below open market value, however, and you as the finder are under no obligation to sell.

Many national governments have restrictions on the exportation of material like meteorites. In Canada, for example, any new find or fall must be offered to interested institutions before being exported; the United States has similar restrictions.

The Geological Survey of Canada, which administers the National Meteorite Collection of Canada, offers a minimum reward of $500 (Canadian) for any new Canadian meteorite find. The possibility of financial gain is a good reason to receive positive permission from a private landowner before conducting a search. In Canada the finder receives a handsome framed certificate from the Associate Committee on Meteorites of the National Research Council of Canada in recognition of this worthwhile achievement. (Personally, I'd rather keep the meteorite.)

Scientific interest in meteorites is especially intense at this time because meteorites give us invaluable information about the early history of the solar system and the early history of planetary formation and differentiation. In fact, some of the amino acids found in carbonaceous chondrites bear a resemblance to those found in the human body. Therefore, as the supply of meteorites is limited, any new one, whether a fall or a find, is scientifically useful.

To this end, I encourage all of you to go meteorite hunting. Amateur meteorite collectors have been responsible for finding and identifying many new meteorites. You can help, too! ☐

Christopher E. Spratt is a member of the American Association of Variable Star Observers and the Victoria Centre of the Royal Astronomical Society of Canada. He lives in Victoria, British Columbia.

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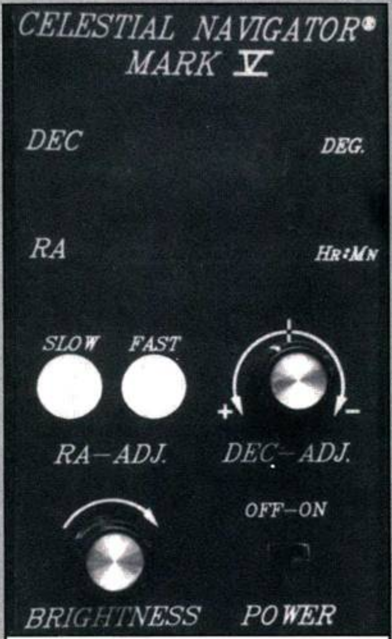

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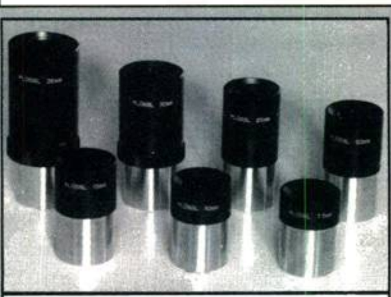

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Great Astrophotos in Less Than an Hour

Custom-quality color prints can be yours in minutes from the "one-hour" photofinishing shop at your local mall, if you know how to speak their language.

by Robert Bunge

Modern high-speed color negative films have revolutionized deep-sky astrophotography. Until recently, however, astrophotographers used slide films almost exclusively because it is difficult to get a good print from a color astro-negative. The central problem was, and is, very simple: Unless the person who's printing the negative knows what the object is supposed to look like, the chances are slim for getting a print that an astrophotographer will like.

Printing color negatives can be a highly rewarding form of art, but it also requires a substantial investment in darkroom equipment and patiently learned skills. If you're a would-be astrophotographer who wants to cash in on the high-speed revolution without getting tangled up in bleach-fixes, developers, and all that messy, smelly stuff, then take a tip: head for the nearest one-hour photo lab.

One-hour photofinishing puts a highly sophisticated darkroom at your fingertips — without the expense and hassle of owning it yourself. Think for a moment about the old system. You handed in your roll of film at the camera store. It was taken to a vast photo factory where anonymous technicians developed and printed your pictures. Finally, after a week or so, you got a washed-out Orion Nebula with pale pinks instead of rich hydrogen-alpha reds.

But in a one-hour lab, the "anonymous technician" sits and works not ten feet away from you. Provided you visit when the store is not busy with customers, you can talk to the person making the print and give accurate instructions. This cuts out that whole chain of intermediary people who took away all your control over how your astrophotos were printed.

Surprisingly, many astrophotographers don't realize that the printing process in a photo lab allows a lot of control over how the print will look. You don't have to settle for whatever the machine pops out on its first attempt. Also, keep in mind that when you try out that hot-shot film and the prints come back with a brown-green sky, it's probably *not* the fault of the film. It's just that the person checking the quality of the prints before they were given back to you simply didn't know what M31 is supposed to look like.

So what's to be done? The problem confronting you lies in putting together a foolproof routine so that you and a couple of people with no astronomical experience — but a super printmaking machine — can turn those great astro-negatives into outstanding prints.

The first step is preparation. It's only human to want to dash your photos into the lab the morning after you took them because you want to see them right away. However, a few minutes' homework may improve the quality of the prints markedly, without doing anything special in a photographic sense.

Spend some time leafing through ASTRONOMY for a picture or two of the same subject you photographed. Try to find amateur photos taken with the same film that you used. Mark the pages with these sample pictures so you can find them readily. Show the samples to the clerk at the photo lab and explain that you would like the finished print to "match" the sample as closely as possible. "Match it" is what the photo technician will be expecting to hear. He or she will then try to make your print look like the sample.

When you pick up the prints, examine the results before you leave. How closely did the photo lab match the samples? The photographs on pages 80-81 and 82 are designed to help you and the technician assess how far off your prints are. Prints can go wrong in two unrelated ways — color and darkness — and it's important to separate the two effects.

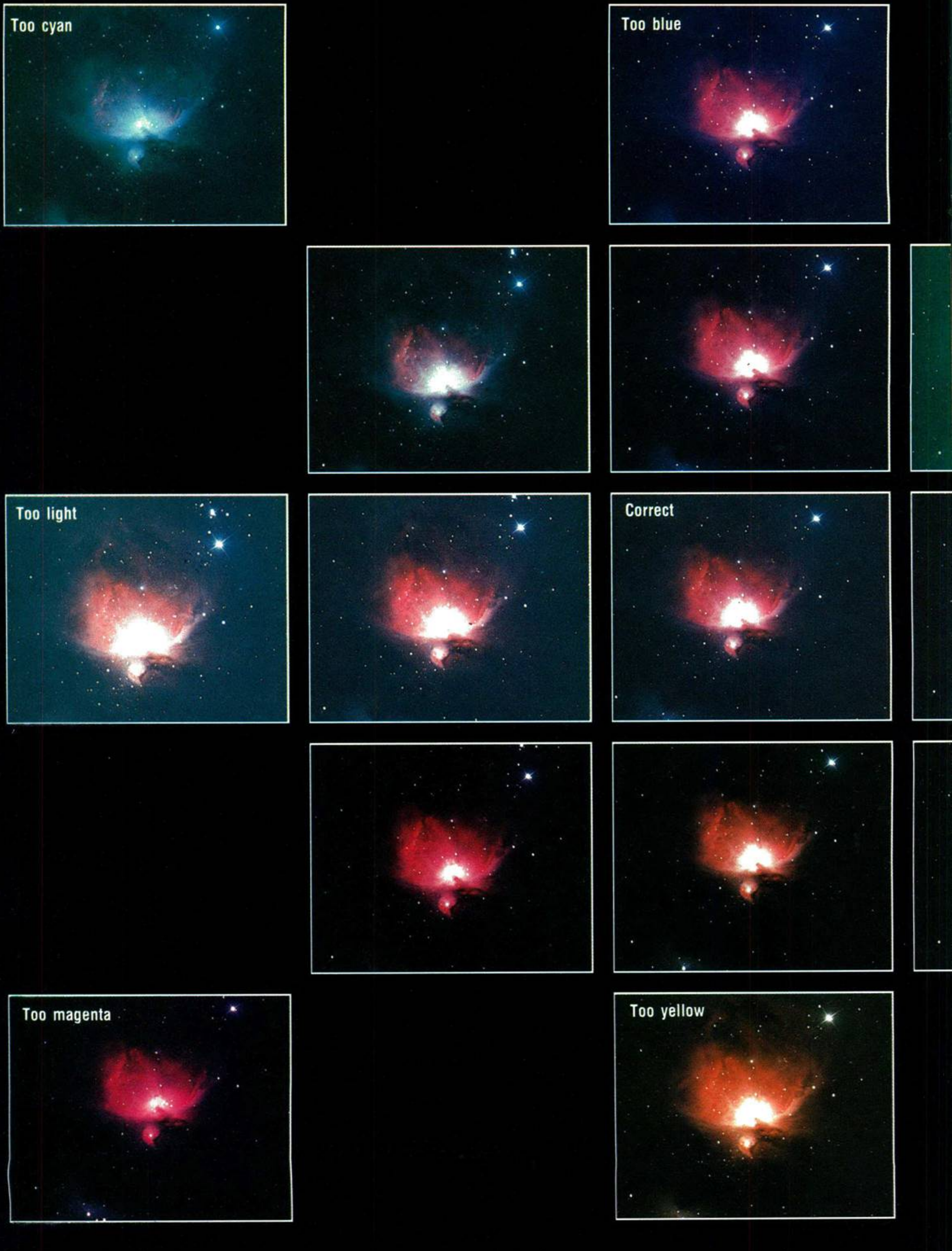
For instance, the sky around M31 may be dark enough for your taste but the galaxy looks, well, *green*. Or a fine negative of M42 has wisps of nebulosity extending to the edge of the frame, but the print shows only the inner parts of the nebula. The print of M42 is certainly too dark; it may also have a color shift or it could be exactly right — look closely.

Be sure to examine the orange-colored negatives as well as the prints and learn how to "read" them. Use a magnifying glass to look for good detail, sharp focus, and proper exposure. You should be able to see through the black sky portion of the negative with little difficulty, yet there should be a distinct edge where the black sky gives way to unexposed film.

Chances are the people working at the lab haven't seen many astrophotos and will be interested in what you have done. It may also help if the staff understands the effort you've put into each of your photos. They probably don't realize that deep-sky photos require exposures lasting many minutes while you stare into an eyepiece. Be friendly and low-key about it; don't come across as overbearing.

There's another point to remember, too. The photo lab is a business. While they will correct free of charge any honest errors on their part, you don't want to become known as that tiresome, cranky customer who's never satisfied. Ask for special requests during slow periods and make sure they understand you don't mind paying for prints that are basi-

GETTING THINGS JUST RIGHT is a challenge, but one-hour photo labs can make great astroprints. This shot of M42 is an enlargement of the central photo in the array on the next two pages.


Too cyan
Too blue
Too light
Correct
Too magenta
Too yellow

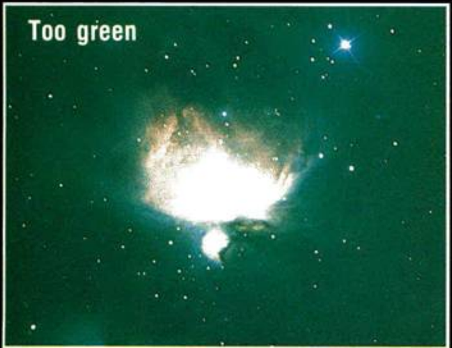
Circling in on the Perfect Print

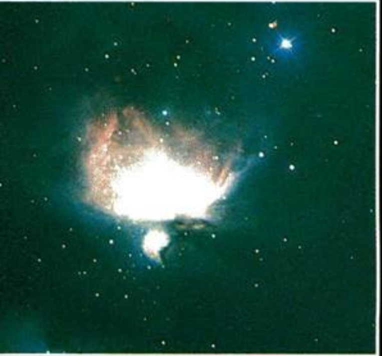
The prints on these two pages make up what photo technicians call a "ring-around." It is your key to getting the best possible prints from your astro-negatives. Made from a single Konica 3200 negative, the ring-around runs the gamut of variations in density and color.

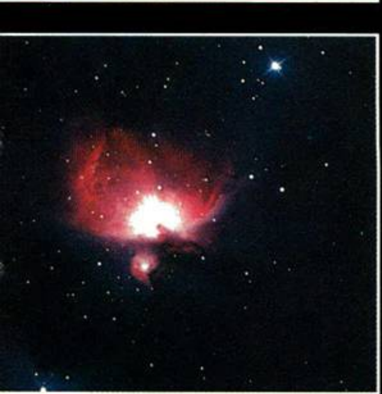
The ring-around starts at the center with a print of good density and color. Movement away from the center in any direction represents a "bad" print of one kind or another. In the row across the center, density darkens toward the right (also see page 82). Prints in the upper part of the page are too cool in tone; those at the bottom are too warm.

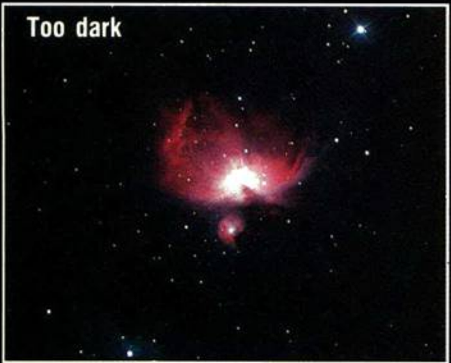
As a rule, you have to get the density (darkness) right before you can make a good judgement about color. An experienced operator can assess color quickly, often viewing a bad print through a series of standard color filters. You can buy these at a photo store and learn to judge print corrections yourself, but offer such opinions cautiously at the photo lab. Otherwise, the operator might give the print exactly what you ask for — whether it's right or wrong.

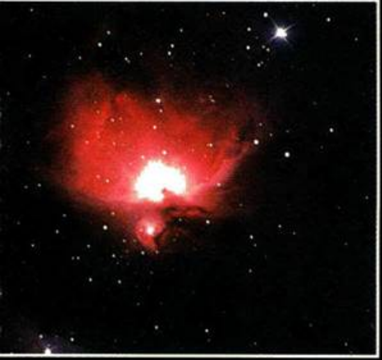
(Note that you can get intermediate mixes of color and density between those shown here. Also, with the Kodak system I used to print the Konica negative I found it very difficult to make a print that was too yellow.)

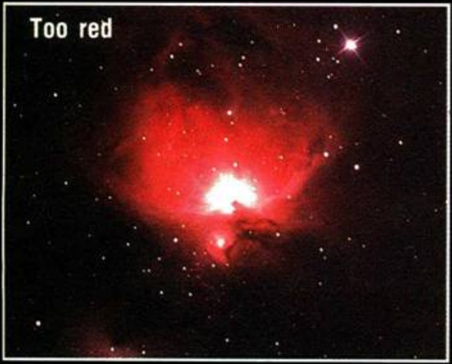








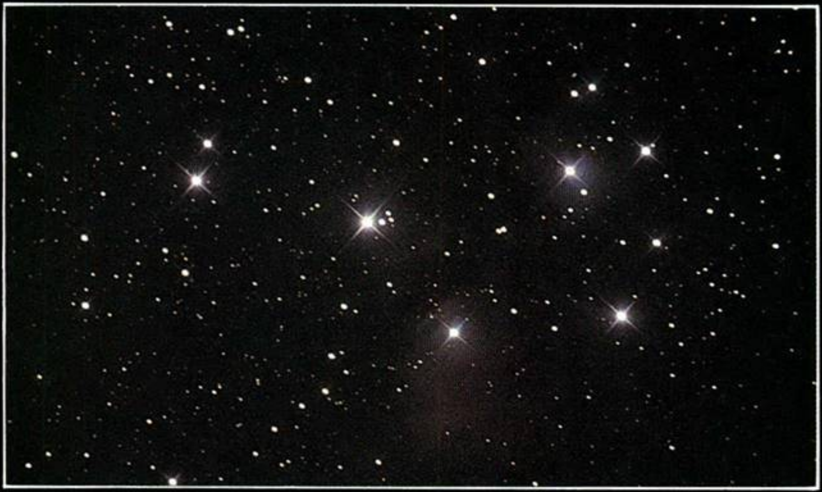




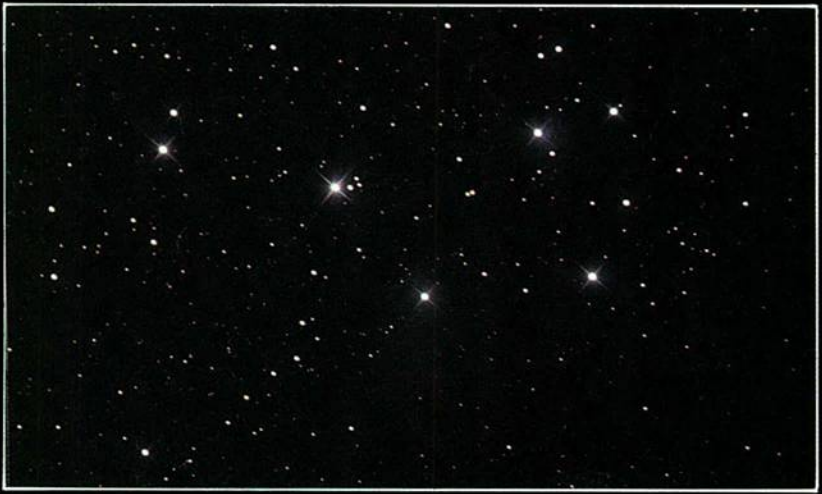
Varying Color and Density

The series below shows a Fuji one-hour system zeroing in on the correct blend of filters and exposure. Note how in the middle print increasing the exposure "to make the sky black" destroys a lot of nebulosity.

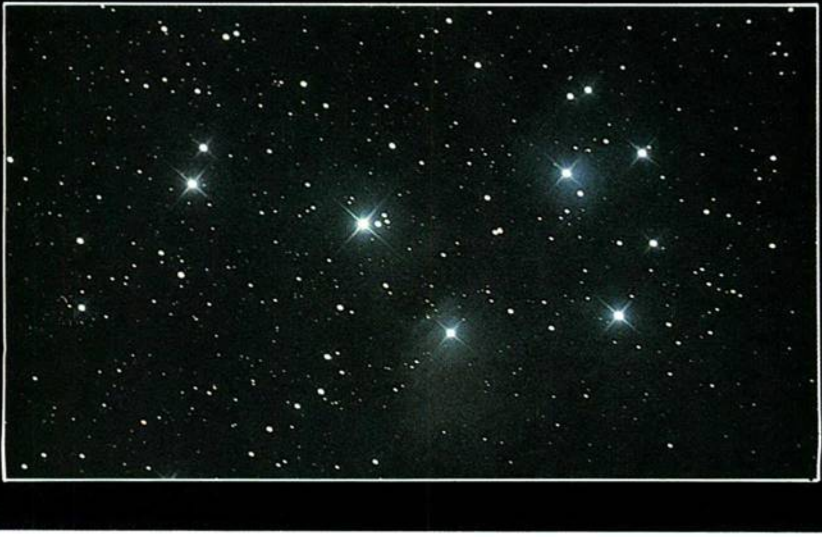
#1 Too red and too yellow

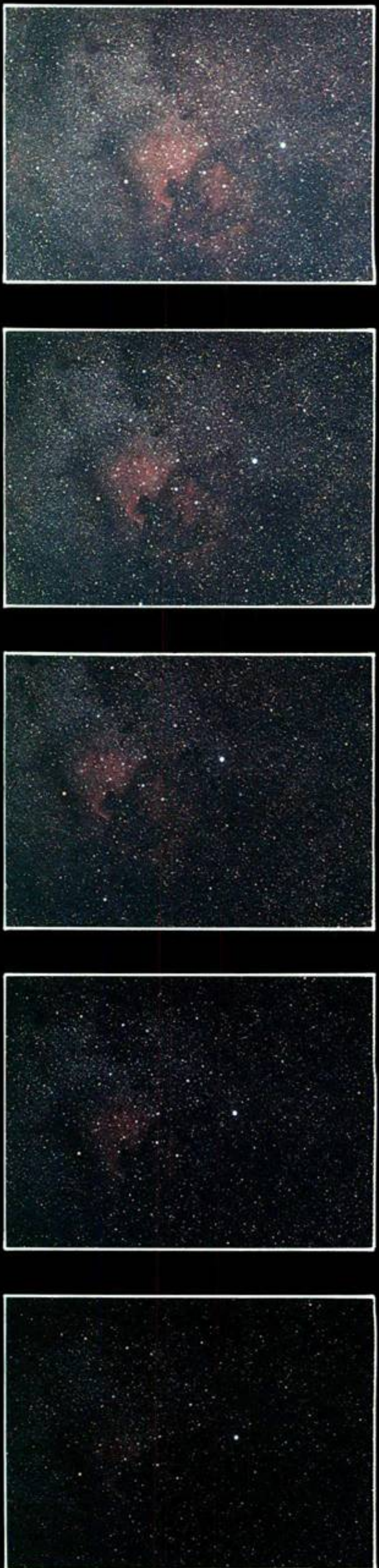


#2 Same filters, longer exposure



#3 Short exposure, correct filters





The series of photos above shows the results of doubling the printing exposure while leaving the filters unchanged. The shortest exposure is at the top.

cally experimental. You'll find the staff becomes much more cooperative when everyone understands that the lab isn't going to be stuck for the cost of all your trial-and-error prints.

Once you find a lab where you are happy with the results, keep going there. If you shoot quite a bit of film or have a lot of prints made, the lab will be interested in keeping a set of prints that you like so their operators will know what a print should look like. And who knows, someday you just might find a print of one of your photos displayed on the wall next time you bring film in to be processed!

Your goal is to teach the people who make the prints what astrophotos look like, and a good way to do this is to arrange for all of the astrophotographers in your club or area to take their business to one lab. When you do this, not only do the operators learn what astrophotos look like, but the management may realize that there is a specialized market they can sell to and will be more interested in working with you. They may also take pride in serving an unusual, but highly pictorial, speciality.

On your part, understanding how prints are made may help you and the technicians avoid some of the more common pitfalls. The color of the print made from a negative is controlled by inserting a selection of different colored filters, called the filter pack, between the light source and the negative.

The computer-controlled machines in one-hour labs have sophisticated light meters that scan the negative and decide what filters to use. In a typical machine, there might be three scanners, one for each of the three primary colors (red, yellow, and blue). The filter pack used for each negative varies for many reasons. For example, the type of film, the color of the light (indoors or outdoors) that the film was exposed to, and even the density or darkness of the negative all influence which filter pack to use.

Most of the one-hour machines are set up so the operators select both the film and light type used (experienced operators learn to see the difference), while the computer picks the right filters and inserts them in the light path. The scanners also tell the computer how long the paper needs to be exposed.

Astrophotos can easily fool both operator and scanner. Why? Because no astrophoto will ever resemble Aunt Sylvia and Uncle Bill standing in front of the boatshed last Fourth of July. The color of the subject, overall density, contrast, even the color of the light captured by the film are all utterly different in an astrophoto from what the machine was programmed to expect.

When the photo technician realizes that your negative is not of Aunt Sylvia, he or she can override the automatic filter choice, but the chances are good that the first print is going to come out very wrong. The operator will then change the filtration and printing time to correct the color and the density of the print. This is called remaking the prints and each time it happens the lab incurs a small financial loss.

Technicians have to keep down the number of remakes — or they'll lose their jobs. This is where your offer to purchase trial prints greases the wheels so that no one feels they are being taken advantage of. If you bring in astrophotos often, the machine operators will soon have a good idea (or perhaps keep a record) of what filters and exposures are needed.

When you critique a trial print, it is not a good idea to tell the technician to "make the sky black." If the first print comes out with a weirdly colored sky, one way to blacken the sky is to leave the filter pack unchanged and increase the exposure to darken the print overall. This will wipe out faint details in your negative, however. Therefore, it's a lot safer to ask for a neutral sky and get them to correct any color errors by filter instead.

Do not expect too much from a bad negative. Prints made from underexposed negatives show only what is on the negative. Overexposed ones are usually more salvageable, because the operator can project more light though the negative. Also, don't expect an absolutely perfect match to the sample you brought in — magazine printers use different dyes than those used in photo paper.

If you take several different exposures of the same object, ask the operator to turn off the autosensors and to use only one exposure. Otherwise the computer will vary the printing exposure and do its darndest to make all the prints match one another. You could easily wind up not being able to tell which print came from which negative!

It is also important to realize that each of the film manufacturers has a processing system that works best with their own film. A lab using Kodak equipment, paper, chemicals, and dyes may encounter difficulties printing Konica or Fuji films. It works in reverse too: Fuji labs may not be able to get good prints from Kodak films. In addition, some labs do not like to work with "other" films and may refuse to remake prints after the first try. Be sure to ask about this the first time you take in your film.

Unfortunately, not many labs use Konica or Fuji chemicals and paper, so astrophotographers using Konica 3200 or Fuji 1600 may not get the best results possible. To compound the problem, the super-speed films are seldom used by snapshooters. Because labs don't often see these films, they don't program the machine for them. This is another reason for area astrophotographers to patronize one lab. If there's a local market, you may convince them to prepare for astrophotos using super-speed films.

A note about the custom photo labs you'll find in your local Yellow Pages. These tend to be oriented toward professional photographers shooting weddings and portraits. Their systems are completely different from one-hour labs, often using a machine that shows a positive image of the negative on a video screen, so the operator can experiment with filters before the print is made. However, professional photographers tend to use one or two kinds of slow films; thus the systems in custom labs are very specialized. The upshot is that "custom" labs probably won't be as adaptable for your needs as the one-hour labs.

The final prints will depend a lot on your tastes. Every person sees color a little bit differently, and astrophotographers often have different ideas of what makes a good looking print, anyway. If you are just starting out, you will soon develop a style you like. If you have been doing this for a while, you probably have a style already. If so, take in a representative sample so the lab can try to match it.

Be sure to take care of your negatives. All too often, astrophotographers lavish great attention on prints — and leave negatives where they get scratched, bent, or dirty. Remember, prints can be replaced but negatives have to be reshot. Store negatives in sleeves of polyethylene or polypropylene (but not glassine or vinyl). These are available at photo stores. File the negatives in binders for further protection.

Getting good prints from your astro-negatives is very rewarding — after all, it's what you labored all those hours for! Isn't it worth a little effort to find a good lab and work with them to make outstanding prints? ☐

Robert Bunge is an experienced amateur astronomer and astrophotographer who lives in Columbus, Ohio. He worked at a photoprocessing laboratory for five years.

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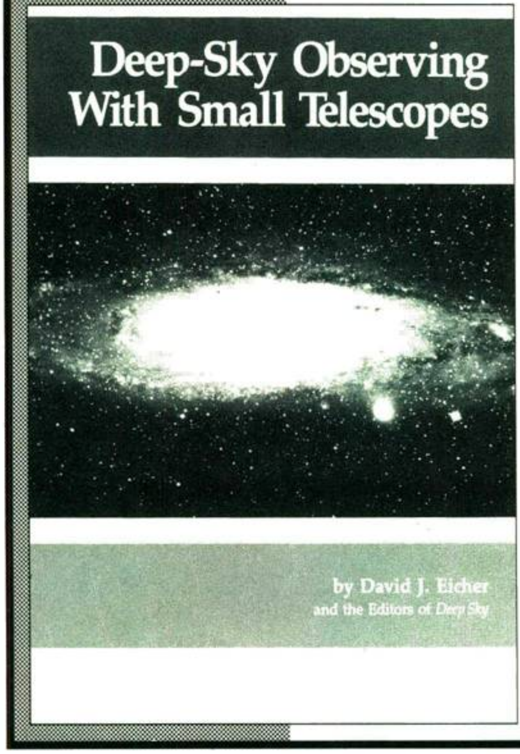
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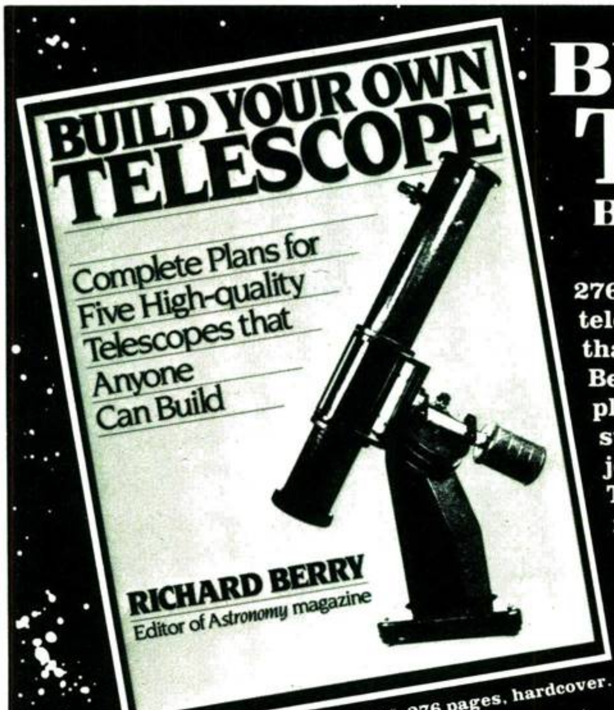
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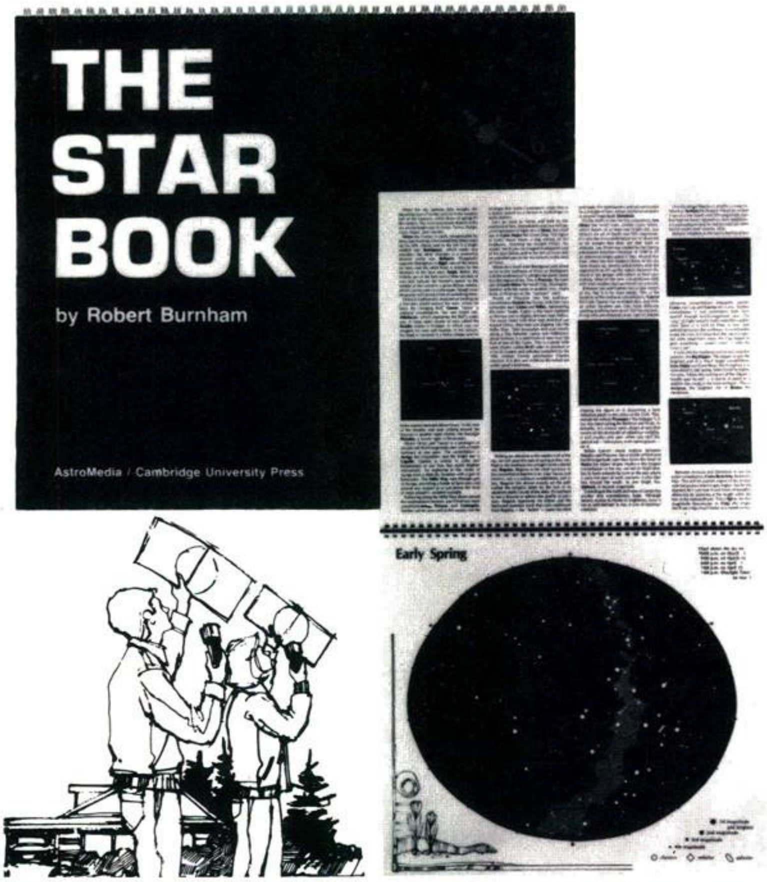

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Rewarding Star Clusters

Small scope owners can sharpen their observing skills by searching for these five challenging star clusters.

by Alister Ling

Star clusters are the most forgiving deep-sky objects. Because they are composed of stars rather than dim nebular glows, you can see them on any clear night, even if the Moon is in the sky. They don't require great transparency, either, as faint nebulae do.

Star clusters come in two types: open and globular. Open star clusters are loose groups of a few dozen or a few hundred stars bound by gravity that orbit our Galaxy's center. All open clusters visible in backyard telescopes exist in the gas-rich disk of our Milky Way Galaxy. Other galaxies also contain open clusters, but they are too remote to observe.

Unlike open clusters, a few globular clusters in other galaxies are visible in small scopes. Globular clusters are spherical balls of hundreds of thousands or millions of stars floating in the haloes of galaxies. They are much larger and intrinsically brighter than open clusters, although in telescopes globulars appear smaller and fainter than open clusters because of their great distances from Earth.

Although most star clusters are easily visible in small scopes, some challenge observers by presenting subtle details. One such cluster is **M29** (NGC 6913), a pretty group of stars in Cygnus. Located 2° south of the bright star Gamma (γ) Cygni, M29 stands out as a bright, compact group consisting of eight 9th-magnitude stars and a handful of fainter ones. The cluster measures a mere 7′ across — a quarter of the diameter of the Moon's disk.

Because it is bright and compact, M29 is visible in small scopes even on slightly hazy or moonlit nights. M29's compactness also makes it stand up well to high magnification. Admittedly this cluster is a star-poor object — someone once characterized M29 as the "dullest Messier object" — but if you view it critically you may discover a few unusual aspects of this underrated deep-sky object.

A 3-inch telescope at low power shows M29 as a round clump of bright stars. Once you locate the group, switch to 80x or 100x for a better look. I noticed that the cluster's eight brightest stars are arranged in the form of a backwards "K." The pattern reminded me of a squashed, miniature version of the constellation Hercules. On the cluster's southern side, I observed an almost perfect square consisting of four of the bright stars and a smattering of fainter stars. One of the faint stars, just outside of the box, is distinctly orange during moments of good seeing.

If you're observing with an 8-inch or 10-inch scope, try using higher power. At 150x, you'll see three faint stars inside the square asterism. Another six faint stars, all pale white, appear at short distances west and north of the box. Should you be observing under a dark sky, you'll see another dozen or so faint stars — so many that M29 appears far different than it does on a hazy night or in a light-polluted sky. Although at first glance M29 appears to be a dull object, the cluster nonetheless shows a lot of interesting features if you take the time to look for them.

When you've finished gazing at M29, switch back to low power for an experiment. Try looking slightly away from the center of the cluster and then directly toward it. Continue to switch back and forth a number of times. By looking away from center, you allow the cluster's light to reach the most sensitive part of your eye. Suddenly, almost miraculously, the fainter stars seem to "pop" into view. This technique, called averted vision, will probably net you additional stars you otherwise would have missed.

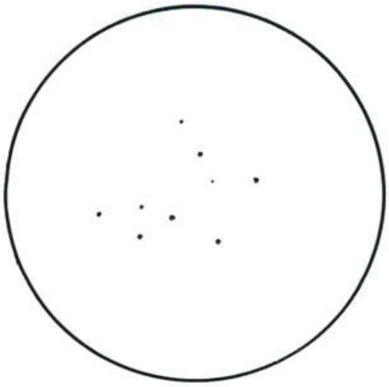
You'll need averted vision to appreciate the challenging open cluster **NGC 188** in Cepheus. Located near Polaris, NGC 188 is a dramatically different cluster than M29. A small telescope reveals that NGC 188 is nearly twice as large as M29 but is composed of much fainter stars. This cluster's brightest members dimly glow at 12th magnitude, making them difficult to see on hazy or moonlit nights.

A 6-inch telescope at low power shows NGC 188 as a large, misty cloud with a few glistening points of light spread across its surface. The dozen brightest stars visible in this cloud are actually foreground objects and are not members of the cluster. However, by using averted vision you'll see a smattering of the cluster's brightest members.

As with M29, higher powers let you see more detail in NGC 188 — but there the similarity ends. With high powers NGC 188 looks like a great cloud of misty stars superimposed on two parallel lines of bright stars at the cluster's center.

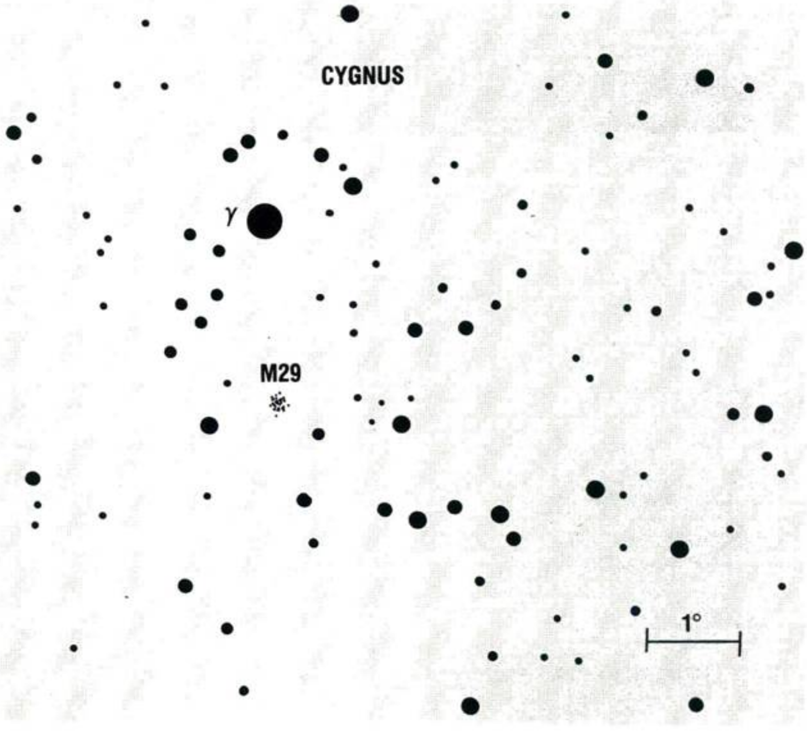
Not much richer than NGC 188, the globular cluster **NGC 5053** is a loose ball of stars in Coma Berenices. To see this object you must observe under a dark sky. Finding its position is easy with an equatorial mount. Once you're set up, plop in a low-power eyepiece, point your telescope at Alpha (α) Comae Berenices, turn off your drive, and wait six-and-a-half minutes. Earth's rotation will carry the cluster into view.

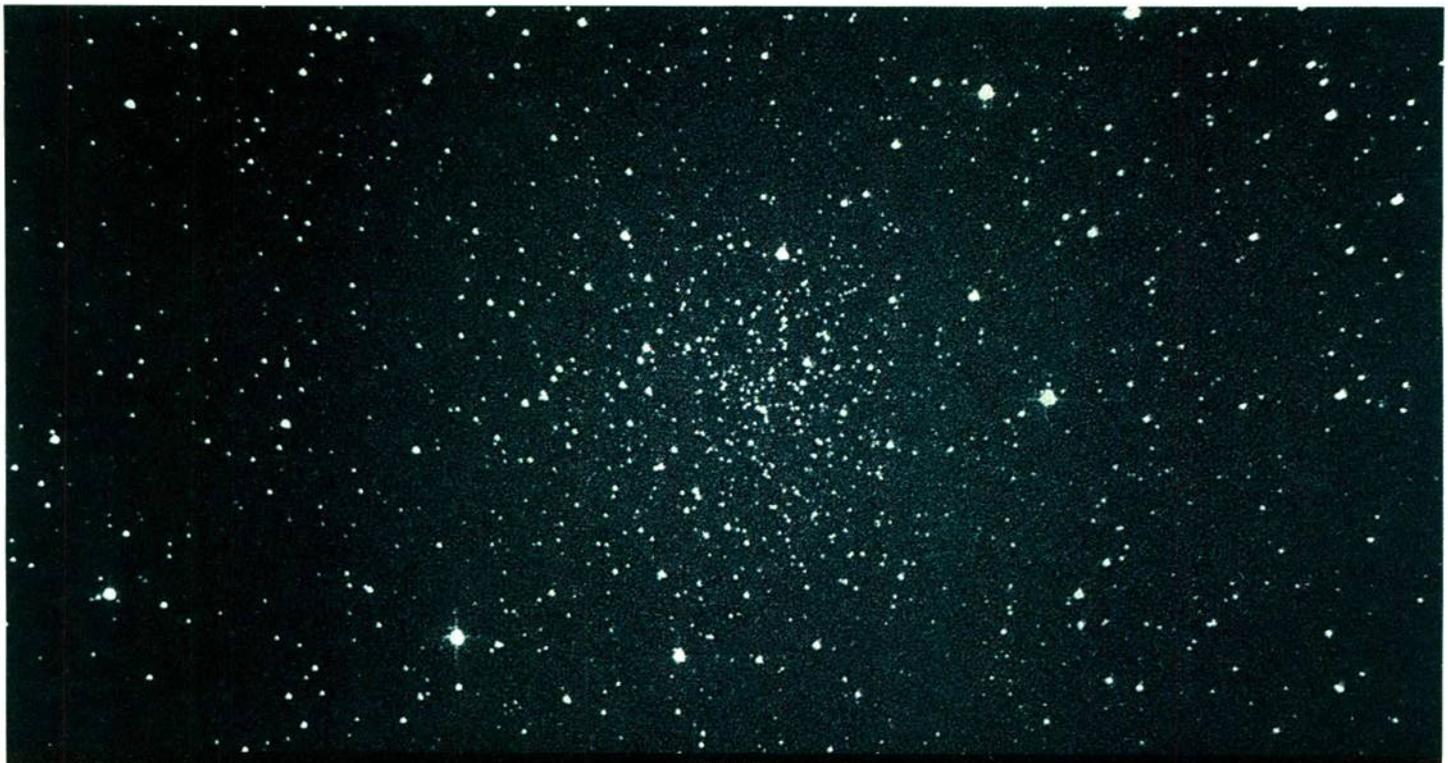
M29
Magnitude 6.6 Size 7′ by Lee C. Coombs



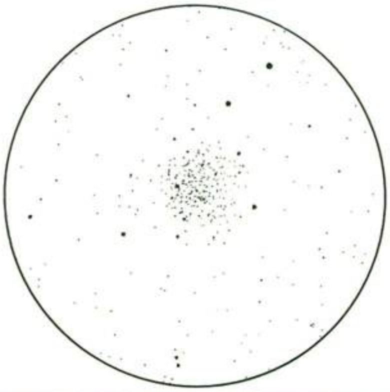
M29
8-inch f/6 at 80x by Alister Ling

A SMATTERING OF BRIGHT STARS, M29 is visible in small scopes at low power. Find it 2° south of the bright star Gamma Cygni.

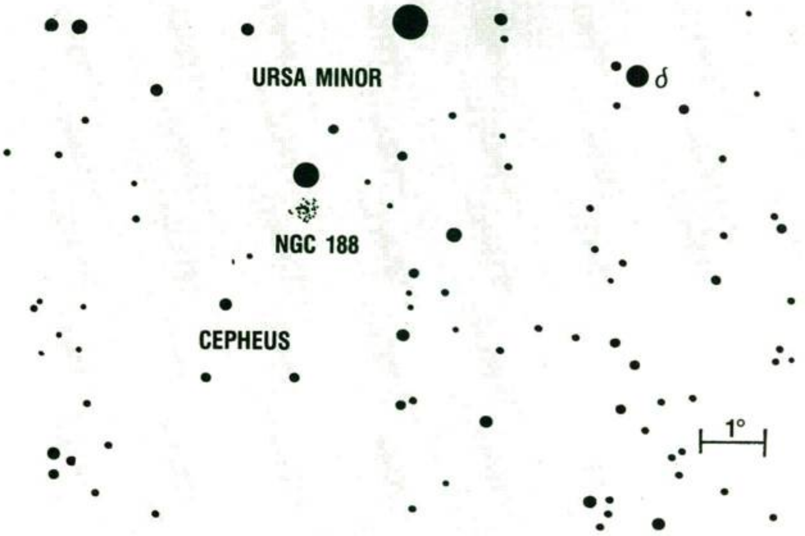




NGC 188
Magnitude 8.1 Size 14′ by Lee C. Coombs



NGC 188
8-inch f/10 SCT at 50x by David J. Eicher



NGC 188 IN CEPHEUS is a rich cloud of faint stars in moderate-sized telescopes.

Challenging Clusters

Object	R.A. (2000.0)	Dec.	Mag.	Size	*Tirion*	*Uranometria*
NGC 188	0h44.4m	+85°20′	8.1	14′	1,3	I: 1,2
NGC 1049	2h39.7m	−34°17′	13.7	0.5′	18	II: 354
NGC 5053	13h16.4m	+17°42′	9.8	10.5′	7,14	I: 150,195
M29	20h23.9m	+38°32′	6.6	7′	8,9	I: 119,120
M73	20h59.0m	−12°38′	—	2.8′	16	II: 299

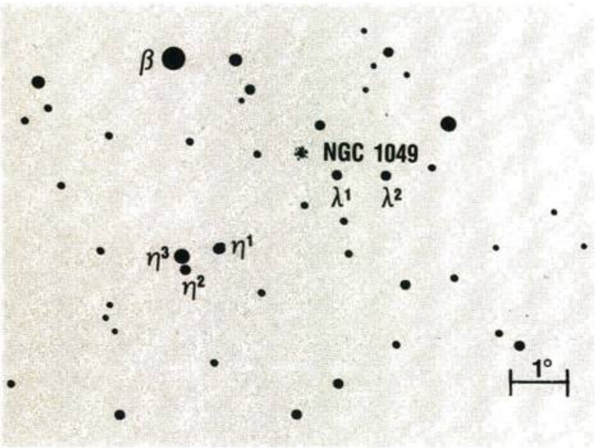
Object: Designation in Messier or NGC catalog. **R.A. and Dec.:** Right ascension and declination in equinox 2000.0. **Mag.:** V magnitude of cluster. **Size:** Diameter in arcminutes. ***Tirion:*** Chart on which object appears in *Sky Atlas 2000.0* by Wil Tirion. ***Uranometria:*** Chart on which object appears in *Uranometria 2000.0* by Wil Tirion, Barry Rappaport, and George Lovi.

With an 8-inch scope you'll see a dim, oval cloud of light elongated slightly east to west. To make sure you're seeing the cluster and not an anomalous background sky glow, turn off your clock drive and watch the field of view. If the glow moves with the sky background, you're viewing the cluster and not an anomalous brightening.

At some point you may have passed right over the next object, the tiny cluster **M73** (NGC 6994). Located in Aquarius near the bright globular M72, this object is one of the simplest of all deep-sky objects. M73 consists of four stars glowing between 10th and 12th magnitude. In fact, many astronomers believe that M73 is not a physically linked cluster at all, but merely a chance alignment of four unrelated stars lying at different distances.

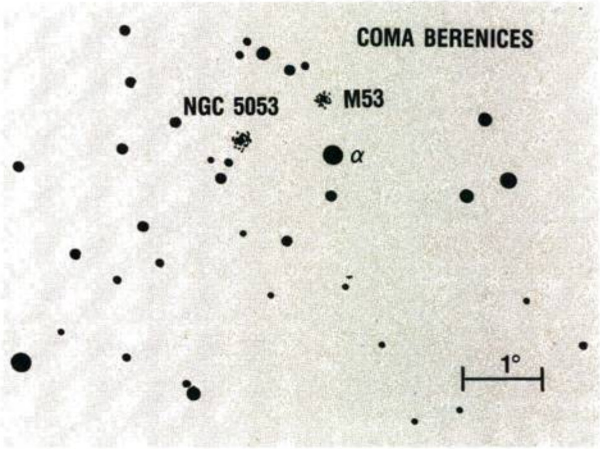
At first glance, M73 appears like a smaller version

NGC 1049
Magnitude 13.7 Size 30″ by Martin C. Germano



BARELY VISIBLE on the darkest nights, globular NGC 1049 lies inside the Fornax Dwarf Galaxy.

NGC 5053
Magnitude 9.8 Size 10.5′ by Thomas L. Dessert



THE SPARSE CLUSTER NGC 5053 appears as a hazy, circular patch in small telescopes.

of M29. With a small scope you may think you detect some nebulosity associated with M73 (Messier himself recorded seeing some). However, there is no nebulosity present. Try medium or high powers to increase the contrast and put some space between the stars. The illusion of nebulosity is just that, an illusion.

If you put M29 on the bright end of the brightness scale, then **NGC 1049** would be on the other. Unlike M29, globular NGC 1049 is tiny, distant, and impossible to resolve into stars. This object is challenging because it is many times more distant than the clusters in our Galaxy. In fact, it is a member of the Fornax Dwarf Galaxy, another star system in the Local Group of galaxies.

If it were closer, NGC 1049 would resemble the great globular M13 in Hercules. However, at 13th magnitude, NGC 1049 requires a 10-inch scope and a dark sky to be detected. For the best view, wait until NGC 1049 is near the meridian. Then you will see NGC 1049 as a tiny ball of fuzz about the same size as Jupiter in your high-power eyepiece. Remarkably, this globular is visible in small scopes but the Fornax Dwarf itself is not.

The starry sky is full of subtle details and challenges. You can push your scope to its limits or simply have fun and enjoy the sights. Either way, clusters are bright and varied enough to fill your summer observing nights. At the same time you sharpen your observing skills, you can push onward by challenging yourself with the faint gleams from distant stars. ☐

Alister Ling is an amateur astronomer who lives in Mississauga, Ontario. His last article was "Standout Winter Star Clusters" in the January 1989 issue.

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CAPTURING THE UNIVERSE ON PAPER

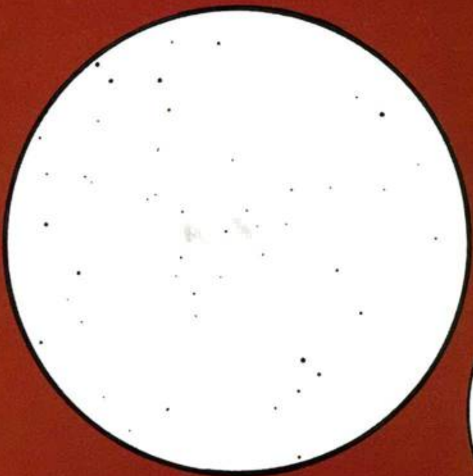
"Drawing what you see in the eyepiece is absolutely the best way to observe," said Michael Sweetman of Tucson, Arizona. "It's a shame that so few people sketch what they see, because it's relatively simple to do and preserves an accurate representation of how objects really appear to the eye." Sweetman has combined his interest in art with a love for astronomy to produce a series of intricately detailed renderings of deep-sky objects. "By learning how to draw what they see," Sweetman continued, "observers can sharpen their ability to see critical details in objects."

Of the many methods available to observers, Sweetman recommends simply using pencil and ink on flat, smooth bond paper. Because most deep-sky objects are inherently low in contrast, Sweetman advocates using the whitest paper available. "You should experiment with papers and techniques of shading," he said, "because some objects show subtle mottling that looks realistic when sketched on slightly rough paper."

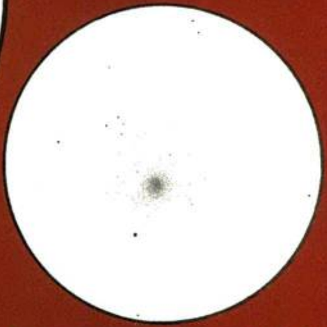
"The area you give a drawing also counts," Sweetman said. "I typically use a circle 4 inches in diameter, and for extremely detailed objects the circle measures 5-1/2 inches across. This gives me enough room to sketch nebulosity but keeps the piece small enough so I can accurately place stars."

Make sure you use pens that are capable of producing small, round star images. "I use technical pens filled with waterproof black ink," said Sweetman. "These let you draw the smallest and most accurate stars you can, and they require no special skills. For nebular shading, use pencils with hard leads, such as a number 1 or 2, and always keep them sharp."

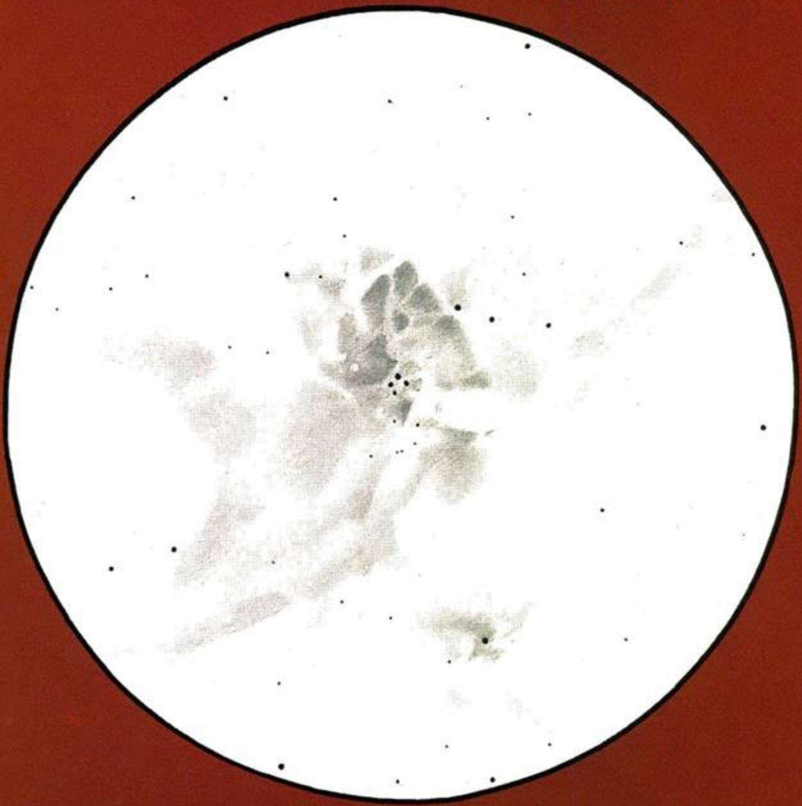
Once you have all the materials, it's simply a matter of plotting the stars and then adding shading to represent the deep-sky objects. Smudging nebulosity with a finger to accurately represent what is visible in the eyepiece becomes second nature after awhile. "It's reasonably easy once you establish a system and get some practice," said Sweetman. "Then you can begin collecting a record of your favorite sights in the sky produced by your own hands. What could be more satisfying?"



THE DUMBBELL NEBULA (M27) in Vulpecula appears like a ghostly apple core at 208x.



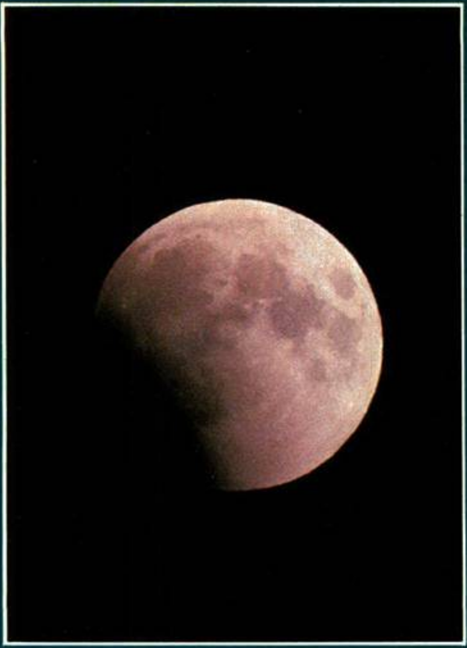
A GLISTENING BALL OF STARS, the globular cluster M2 in Aquarius is cleanly resolved at 288x.



COMPLEX AREAS OF NEBULOSITY surround the central portion of M42 in Orion, sketched at 208x. All sketches on this page were made by Michael Sweetman using his 10-inch f/16 Cassegrain telescope.

WATCH METEORS ON YOUR TV

"Observing from Nova Scotia is a real challenge," reported Michael Boschat of Halifax. "It's a good bet that the weather



A BUSY SPRING FOR THE MOON

Last spring, three exceptional lunar events occurred within two months and sent observers and astrophotographers outside to enjoy some Moon watching. Fred Burger's crisp photo of a First Quarter Moon (opposite) nets this month's $100 "Best Astrophoto" award. A member of the Seattle Astronomical Society, Burger shot the Moon using an f/15 Quantum 6 Maksutov telescope, Tech Pan film, and a 2-second exposure.

In the early evening of April 6, 1989, observers across the country spotted a very young Moon low in the western sky. D. L. Coleman of Dubuque, Iowa, photographed it at an age of 22 hours (bottom left) using a 400mm lens, Kodak VRG 400 film, and a 2-second exposure. Forty-five days earlier, on February 20, observers in the western United States, Alaska, Hawaii, and points west witnessed a total lunar eclipse. Jim Egger captured the event as it appeared from Palmer, Alaska (left). Egger used an 8-inch f/5 reflector, Ektachrome 200 film, and a 1/125-second exposure.

Two days later, the Moon slid across the Pleiades star cluster in Taurus. D. L. Coleman captured the event (bottom) just as the Moon's Earth-lit disk uncovered Taygeta, one of the cluster's brightest stars. Coleman used a 3.7-inch apochromatic refractor, SRV 3200 film, and a 2-second exposure. Tony Hallas and Daphne Mount's photograph of the Pleiades (below) shows the cluster in a dark sky. Hallas and Mount used a 5-inch f/8 apochromatic refractor and Konica 400 speed film.

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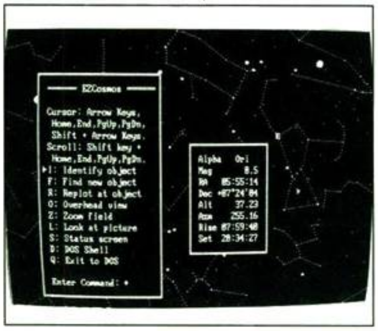

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Mag       0.5
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Alt     37.23
Azm    255.16
Rise 07:59:40
Set  20:34:27
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will be poor during exciting events like bright meteor showers. Rather than becoming depressed when it's cloudy, I've adapted by watching meteors on my TV," explained Boschat. "Thanks to helpful instructions from David Meisel of the American Meteor Society, I've adapted a so-called Yagi antenna to my television set and can now detect meteors on cloudy nights."

"The procedure is fairly simple," said Boschat. "I tune the television to channel 2 (58.90 MHz) and use a passive filter to eliminate ghost images from channel 3. The resulting picture is completely 'snow.' I aim the three-element Yagi antenna toward 222° azimuth and 0° altitude. After this is accomplished, meteors below the horizon deflect the signal toward the antenna and are visible on the TV as a brief flash, a white or black line that appears for about half a second. This happens because the meteor's ionized trail briefly interferes with the television signal. The interference can be significant: I've seen fireballs that have left a signal for as long as twenty-five seconds."

This type of observing isn't without problems, however. Observing is best when the meteor radiant is several degrees below the horizon. When the radiant is high in the sky, few meteors will be visible. Solar activity can affect the image. One time during the Eta Aquarid shower — a period of high solar activity — Boschat picked up the call signal from WTWO Television in Terre Haute, Indiana. The signal lasted for over four hours. Aircraft flying overhead can interrupt meteor observing with periods of signal flutter, and solar flares can completely null meteor signals for long periods.

If you're interested in observing meteors on television, Boschat would like to hear from you. His address is 6363 Liverpool Street, Halifax, Nova Scotia, Canada B3L 1Y1.

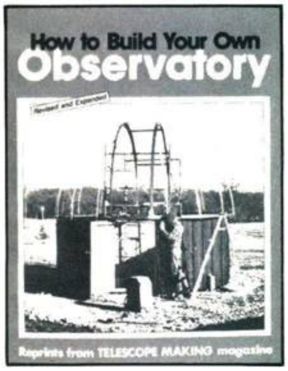
ONE SMALL STEP. . . ONE SMALL SITE

Twenty years ago last month, *Apollo 11* astronauts Neil Armstrong and Buzz Aldrin became the first humans to land and walk on the Moon. Now lunar observers are turning their gaze toward the tiny site on the Moon where the historic event occurred (see "Observe the Apollo Landing Sites" by Michael T. Kitt, July 1989).

Last April Jim Phillips of Charleston, South Carolina, observed the *Apollo 11* site with his 6-inch f/12 apochromatic refractor. "It's almost unbelievable to me that July 20, 1989, marks the twentieth anniversary of the landing," said Phillips. "I have decided to draw all of the Apollo landing sites when lighting conditions are similar to those when the spacecraft landed. For the *Apollo 11* site, April 12, 1989, offered such an opportunity."

The large arrow in Phillips' drawings marks the site of Tranquility Base in the Sea of Tranquility. The smaller arrow close to the Apollo site marks the position of the landing of *Surveyor 5*, a photographic and experimental craft that soft-landed on September 11, 1967. Another small arrow marks the landing site of *Ranger 8*, a hard-landing photographic craft that struck the lunar surface on February 20, 1965. The large crater centrally located in the drawing is Moltke. Phillips encourages observers to "read the ASTRONOMY article and then find out how many Apollo landing sites you can find this summer."

Revised and Expanded!



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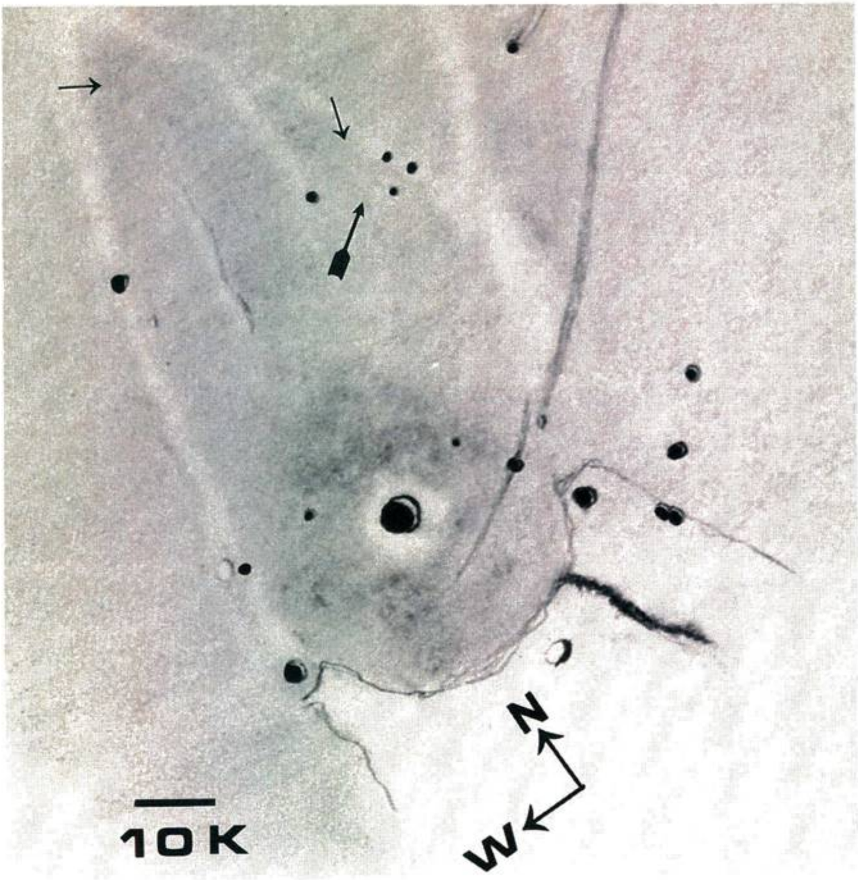

APOLLO 11'S LANDING SITE is marked by the large arrow. Smaller arrows show the landing sites of *Surveyor 5* and *Ranger 8*. Sketch by Jim Phillips using a 6-inch f/12 apochromatic refractor at 205x and 274x.

FLORIDA AMATEURS SPOT PLUTO

"Many thanks to ASTRONOMY for the excellent Pluto finder chart in the May 1989 issue," wrote Bryan R. White of Bradenton, Florida. "After reading Richard Talcott's article, 'Get Ready for Pluto at Its Best,' I absolutely had to haul out my 20-inch f/5 telescope and look for the little speck of light. I found it within twenty minutes, but even in a 20-inch telescope the planet was best seen with averted vision. It was definitely a thrill to observe Pluto for the first time."

"This coming Saturday marks our monthly star party with the 'Local Group' astronomy club," said White. "I'll keep your chart handy, and I'm sure Saturday's viewing of Pluto will be a first for most of the club members. Thanks for the opportunity." — *David J. Eicher* □

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TRICKS OF AN OBSERVER'S TRADE

I eagerly unpacked my new Odyssey I telescope. The sky was clear, and NGC 6826, the "Blinking Planetary," seemed an attractive target. Almost half an arcminute in diameter, it was at magnitude 9 and just half a degree from 16 Cygni. Finding it was no trouble, at least on the star charts.

After forty-five minutes of frustration I still hadn't located the object in the telescope. I started thinking about all the other ways I could have spent the $600 I'd just sunk in the telescope.

Three years later I'd blinked NGC 6826 and observed a hundred other deep-sky objects. What made the difference between frustration and pleasure was a lot of trial and error. I found out the hard way that the obstacles facing the fledgling observer fall into two categories: finding what you're looking for and appreciating what you find. The first calls for patience, the right equipment, and a few tricks. The second, I'm discovering, involves programming your eye-brain system in an entirely new way.

Lacking setting circles or a computer-driven targeting device, I began finding what I was looking for with the only piece of aiming equipment I had: my eyes. At first they didn't do the job. I had a finder scope, but it didn't help much. Translating the relatively narrow, inverted field of stars the finder revealed into meaningful information was beyond me.

Then I bought a Telrad finder. More than any other purchase, that zero-power illuminated reticle gave me access to my telescope. Look through the glass "window" at a target star, center it, move to the main eyepiece, and the star is in the field.

I also invested in a quality 32mm Plossl eyepiece. Big bucks, but it helped enormously by giving me a field about a degree in diameter. The bigger your window on the sky, the more probable it is that what you're seeking will be in the window. Sounds simple, but it took me a while to get the idea, at least to get it clearly enough to convince me to part with $80.

On rare occasions the faint galaxy you're seeking lies near a naked-eye star, but generally you have to star hop to the object. Star hopping! The very term is uplifting, evocative of warp drives and hyperspace. But in practice the cosmic connect-the-dots game can be laborious, especially in the beginning. To succeed, you'll need a good set of star charts. I found *Sky Atlas 2000.0* by Wil Tirion to be perfect for my needs.

Once you've locked on to a target star, there are two tricks to successful star hopping. The first lies in getting oriented. You see the directions clearly on the charts: NGC 4647 lies northwest of M60. But which direction is northwest?

All those helpful declination and right ascension lines on the star charts don't appear in the eyepiece. However, one dark night I realized that the Sun sets in the west and that everything you see in the eyepiece is drifting west too. The moral is to find your target star and then watch it for a while. The direction it's moving is west. East, of course, is the opposite direction, and north and south are reversed from where they should be because the field of view is inverted. Now you're oriented and the charts can begin to help you.

The second trick to star hopping lies in knowing how wide a field of view you have with your lowest-power eyepiece. The faint globular you're looking for lies 2.5° due south of your target star. The star is centered in your main eyepiece and you've figured out where south is. How far is 2.5°?

Using your star charts, find a star on the celestial equator that's currently located above the horizon. Aim the scope so the star is on the edge of the field of view. Make sure your clock drive is disengaged and time how many seconds the star takes to drift across the field. Divide that number by four. The result is the true diameter of your field of view in arcminutes.

Once you can find what you're looking for, the next step is appreciating what you observe. Some objects are knockouts on the first look: the Great Nebula in Orion, the Double Cluster in Perseus, M11 in Scutum. If you have eyes in your head and a heart in your chest, appreciating them is automatic. But most celestial objects are subtle, and learning to enjoy them takes a bit of practice.

Knowing what you're looking at is central to appreciating what you see. That faint puff of light you can barely see doesn't look very inspiring, but it's the remains of a supernova. The heavy elements cooked in the blast might eventually find their way into new planets, new bodies, new intelligence. Knowing that adds a new dimension to what you actually see.

Being aware of what you're seeing is the key to appreciating the rainbow of hues in the stars. At first I was more concerned with tracing spiral arms and pushing limiting magnitudes, but then it happened: Pow! Reds, blues, yellows, more subtle shadings. Look for color and you'll see it. And it will deepen your appreciation of what you're observing, especially if you find out why some stars are blue and some are red.

A few techniques like averted vision require a little practice. Most amateurs get the basic idea early on: don't look right at the object. Your eyes are more sensitive to dim light if you look away from where the faint nebula is hiding. To detect more light, put the object off-center in your telescope, toward your nose. Look straight ahead but pay attention nose-ward. It's amazing what will pop out.

If you live anywhere but the Gobi desert and don't have a light-pollution filter, get one. And, silly as it might make you look, get a heavy cape to throw over your head when you sit at the eyepiece. It's worth the taunts. The cape will do just as much as the filter to improve what you're seeing.

We tend to associate deep-sky observing with low-power eyepieces, and much of the time that's good advice. Still, as I've become more experienced, I've found myself turning regularly to high magnifications. The image degrades and shakes around more, but that's frequently compensated by improved contrast and a bigger image. Contrast, of course, amplifies wispy detail. Image size does too, especially for brighter objects.

Practice is the bottom line of enjoying astronomy. Throw in a few tricks of the trade, give it a year or two, and every clear night will find you star hopping through the universe, perhaps either shivering or swatting mosquitoes, but full of wonder and appreciation nonetheless.
— *Steven Forrest* ☐

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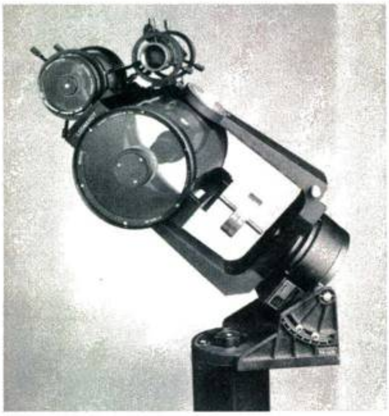

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SOME ANSWERS FROM SUPERNOVA 1987A

The Supernova Story by Laurence A. Marschall, (Plenum Publishing Corporation, 1988,) ISBN 0-306-42955-1, hardcover, 296 pages, $22.95.

Even if it *had* been a typical supernova (if indeed any supernova can be called typical), supernova 1987A would have had remarkable staying power in research astronomy. Not only was it the nearest star death to be observed by the tools of twentieth century astrophysics, but it has been observed practically from the onset of the explosion.

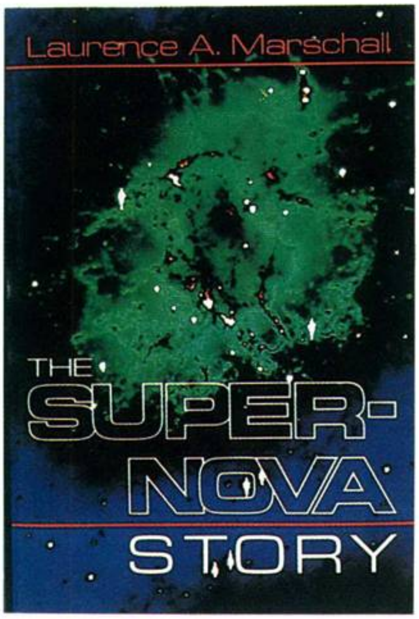
But as we know now, it wasn't a typical supernova — a fact that elevates the event to an unexpected greatness. Fortunately, 1987A occurred at a time when scientists were best equipped technologically to study it. As Laurence Marschall points out in the preface to *The Supernova Story*, had the supernova been 100 light-years closer to us, it would have been seen 100 years earlier, during a time when we were still grappling with the meaning of spectral lines, when photography was in its infancy, and, of course, before orbiting telescopes were even imagined. Marschall writes: "The light [from supernova 1987A] reached Earth during a time of great technological proficiency, a golden age for astronomy."

As technologically ready as we are, however, supernova research has been frustrated by the rare appearance of these exploding stars in our Galaxy. "The brightest supernova," Marschall says, "appeared long before anyone was prepared to recognize or study them. Now that many people are watching and waiting, supernovae in our own Galaxy seem stubbornly reclusive." This atmosphere of "waiting for the big one" sets the stage for the dramatic entry of supernova 1987A.

The Supernova Story is a grand tale that covers a lot of scientific ground, examines some history, and tackles many astrophysical concepts. Yet Marschall, an astronomer and physics professor at Gettysburg College, has managed to tell this sprawling tale in a lucid, eloquent style. Popular science writing is often criticized for either profaning the facts or towing the "data" line to the point of tedium. But in *The Supernova Story*, Marschall has combined his writing talent with knowledge of astronomy to produce an authentic and enthralling science book that is a pleasure to read.

Despite the title, the book covers much more than supernova 1987A. The book opens with a brief overview of modern astronomy, then quickly shifts into the main topic, which begins with an historical account of how ancient astronomers perceived changes in the sky, particularly "new" stars. There follows a chapter on how modern astronomers interpret the spectra of stars and supernovae, a necessary section if we are to grasp the message in the light emitted by supernova 1987A. Next, Marschall delves into over two thousand years of astronomical records to tell us how supernovae were recognized, recorded, and mistaken.

The historical interlude makes way for chapters delineating modern supernova science. Early on, Marschall poses the question: Why was supernova 1987A such a big deal? He lays out the reasons in chapters dealing with why stars explode, the secrets found in the tattered aftermaths of supernova remnants, the conundrums of pulsars, how supernovae seed intergalactic space, and the roles supernovae play in the extragalactic distance scale and galactic structure.



Marschall presents the specifics of supernova 1987A in the final two chapters. He delves into such issues as the astronomers' ambivalence in determining the type of star that exploded, the importance of the neutrino observations, and the mysterious "dot of light" observed a mere twentieth of an arcsecond away from the supernova a month after the explosion. Marschall also discusses the astrophysical repercussions of 1987A, and in a final chapter explores what the future holds for supernova research.

On one level, Marschall's book is a kind of proclamation of a new era in supernova research. Undoubtedly, the light of future supernovae will be compared with 1987A; therefore it is critical that astronomers glean as much information as possible from this pivotal stellar event. After all, the insights derived from 1987A could very well translate into knowledge when the next big one goes off in our neighborhood.

On another level, Marschall's documentary-like description of the supernova's discovery and subsequent frenzy of international observations is in itself an instructive account of how modern astronomy is done. In the telling, Marschall conveys why so many people find astronomy an exciting endeavor and an endless source of enrichment. It wouldn't surprise me to hear a future astronomer admit how he or she was inspired to go into the profession after reading *The Supernova Story*. — *Jeff Kanipe*

THE GOLDEN AGE OF ECLIPSES

Eclipse by David and Carol Allen, (Allen & Unwin, Inc., 1988), ISBN 0-04-300095-9, softcover, 129 pages, $12.95.

As rounded bits of the Sun are devoured by some mysterious, evil object, animals head for their nests or dens; birds become quiet. Colors flatten out and lose their normal intensity. Shadows soften to ghostly grays. The color of the sky changes from blue to various shades of red and orange, then turns purple before it becomes black. A chill envelops those in the path of the Moon's shadow racing across Earth at 1,500 miles per hour.

For a few moments, the sky remains black. Stars that are normally hidden by the glare of the daytime star appear, and a strange halo of light spreads from a black hole in the sky where the Sun was moments before. Then the sky slowly brightens again, returning light and warmth. But for those who witnessed the Sun's extraordinary vanishing act, the world will never be the same again.

Until ancient man began recording eclipses and learned how to predict them, people feared their gods were upset or the end of the world was at hand as the sky grew dark and the Sun disappeared during a solar eclipse. The Allens' book consists mostly of an historical review of the attempts by astronomers over the centuries to observe solar and lunar eclipses, to understand how they happen, and to study how solar eclipses help in understanding the workings of the Sun.

The first third of the book is devoted to an explanation of the word *eclipse,* the workings of our daytime star, how to safely observe a solar eclipse, and the mechanics of the lunar orbit around the Earth. Maps and diagrams help explain why there is not a solar or lunar eclipse each month as well as the nature of the Saros cycles for solar eclipses. A solar eclipse occurs along the same general path every 54 years and 31 days. (One Saros cycle lasts roughly eighteen years.) About forty Saros cycles are operating at any given time, with new ones starting and old ones ending.

I found the most interesting part of this book to be the descriptions of the numerous solar eclipse expeditions conducted since the late 1700s up to the early part of this century. This period of intense interest in solar eclipses is referred to as the "golden age of solar-eclipse observation," even though it occurred before the convenience of air travel and eclipse tours! You get a feeling for the hardships and sometimes the despair these observers faced just getting to a remote site, not to mention dealing with an unfamiliar and sometimes hostile environment. Because their mobility was severely limited, their goal of observing an eclipse was often quashed by clouds or snowstorms.

Other times, observers met with considerable success. For the solar eclipse in 1835, Francis Baily travelled to Jedburgh, Scotland, and observed sunlight streaking past the mountains and valleys of the Moon's limb just seconds before totality. In his report to the Royal Astronomical Society (responsible for most of the early eclipse expeditions) Baily described the pearls of sunlight rimming the Moon's limb, a phenomenon we now call Baily's beads.

The first photograph of a solar eclipse is a daguerreotype taken during the 1851 eclipse over northern Europe. (A copy of the photo is included in *Eclipse*.) The question of the day was the possible cause of the corona and prominences. Some scientists believed they came from the Sun, while others believed they were escaping lunar gases being backlit by the Sun. At the eclipse of 1860, a British observing team proved unequivocally that the corona and prominences were of solar origin.

The last portion of the book covers observing tips and the reactions of people who have observed a total solar eclipse. Tables giving the time and place for both lunar and solar eclipses for the rest of this century are included.

I found *Eclipse* easy to read and an entertaining treat. Its nonscientific language makes it a good book for anyone interested in observing a solar or lunar eclipse. It is loaded with interesting facts, diagrams, and photographs. The authors did a first-rate job of tying together the history and scientific nature of eclipses. *—Robert A. Garfinkle*

SCIENCE AND THE FUTURE

Infinite in All Directions by Freeman Dyson, (Harper and Row Publishers, 1988), ISBN 006-03-90816, hardcover, 321 pages, $19.95.

It is always entertaining to watch an extraordinary mind go through its paces, as physicist Freeman Dyson's does in *Infinite in All Directions*. Essentially a recasting of Dyson's 1985 Gifford Lectures, entitled "In Praise of Diversity," this book gives the reader one scientist's distinctive view of the future.

Dyson's life's work has been a testament to the power of imagination and science. Much of his research has been in the field of quantum electrodynamics, but he is perhaps best known for his speculations on extraterrestrial life. In the 1960s Dyson proposed that an advanced civilization might capture the visible light from a star using absorbing spheres and parlay the energy to their technological advantage. These "Dyson spheres" would resemble newly formed stars, making it difficult for astronomers to discriminate between a natural object and a by-product of an advanced civilization.

In *Infinite in All Directions*, Dyson steps back from pure physics and addresses the universe in all its diversity and fragility. The first half discusses the expansion of life into the universe. The second half, closer to home, deals with our ability to extinguish life on Earth through nuclear weaponry.

In the early chapters, Dyson focuses on religion and its association (and nonassociation) with science. The age-old feud between the evolutionists and anti-evolutionists, Dyson claims, placed an artificial barrier between religion and science. Because of this barrier, imaginative thinking and problem solving on both sides are crippled. Dyson believes that if we are to solve the social and scientific problems of the twenty-first century, this barrier needs to come down.

Dyson also writes about scientific nonconformity. Many great discoveries, he

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argues, come from a synthesis of ideas, often from scientifically and philosophically diverse disciplines. He maintains that such idea unification requires generalist thinkers, not specialists.

Unfortunately, Dyson points out, our educational system produces an overwhelming number of specialists who are limited in broad-based knowledge that might shed light on scientific mysteries. He asks: Where are the generalists of the future going to come from? Dyson admits he has no answer.

Dyson's parting shot concerns nuclear weapons. Nuclear weapons are error-intolerant and, therefore, require constant monitoring. Dyson believes that eventually we will tire of maintaining this unnecessarily expensive system and totally abolish nuclear weaponry. He further proposes that we will use economic and social resources now wasted on such weapons to produce something of value for society.

Infinite in All Directions contains ideas awaiting development in the twenty-first century, ideas that could very well frame the future structure of reality. Dyson's provocative style puts a unique spin on these future issues, which makes for enlightening as well as pleasurable reading. His thoughtful essays are sure to appeal to broad-minded readers whose interests include, but are not limited to, astronomy. — *Jonathan H. Worstell*

A LIMITED HORIZON

New Horizons in Amateur Astronomy: How To Search for Meteors, Planets, Galaxies, Variable Stars, Comets, Satellites, Novas, and More by Grant Fjermedal, (Perigee Books, 1989), ISBN 0-399-51486-4, softcover, 144 pages, $11.95.

The title and subtitle imply that *New Horizons* is a contemporary how-to book for the novice amateur astronomer. Many of the familiar topics are here, such as observing meteors, comets, and variable stars, as well as a section about a new trend — computer-guided telescopes. Nevertheless, *New Horizons* is stultified by lack of depth and an ill-focused purpose.

The coverage of each topic ranges from bland to superficial. For instance, in his description of how to estimate a variable star's magnitude, Fjermedal arcs through the bracketing method in less than five hundred words. The difficulties often encountered with this method — just locating the star and orienting the charts to your field of view — are hardly mentioned. Instead, Fjermedal sends the reader off to other books and resources for more information.

Furthermore, the book doesn't present an accurate picture of contemporary astronomy. Deep-sky observing and astrophotography are virtually ignored, and planetary observing might as well have been. Moreover, some of the topics seem out of balance with the intended audience. For example, photoelectric photometry and CCD imaging — endeavors not many beginners are likely to engage in — are discussed at length in one chapter.

The reader may also tire of reading one effusive quote after another from amateur astronomers. A little of this is fine, but Fjermedal goes too far in spreading around everyone else's enthusiasm. Naturally, many of the quotes tend toward the "universe-is-awesome" theme. But after the fourth or fifth quote, the hormonal glands simply stop responding.

New Horizons is a Sunday-supplement treatment of amateur astronomy in the guise of a how-to book for beginners. More space should have been alloted for techniques and less for the commentaries of amateur astronomers. — *Jeff Kanipe*

ASTROPHYSICS

Astrophysics of Gaseous Nebulae and Active Galactic Nuclei by Donald E. Osterbrock, (University Science Books, 1988), ISBN 0-935702-22-9, hardcover, 408 pages, $36. A graduate-level reference and text, nine-tenths of which covers the different types of gaseous nebulae as probes of the chemical evolution and star formation history of our Galaxy. The final two chapters look at the analysis and interpretation of active galactic nuclei.

Astrophysics and Space Physics Reviews, volume 6, parts 1-5, edited by R. A. Syunyaev, (Harwood Academic Publishers, 1988), ISBN 3-7186-4837, 4838, 4839, 4840, and 4841, respectively; all copies are softcover; 102 pages (part 1), 91 pages (part 2), 117 pages (part 3), 111 pages (part 4), 151 pages (part 5); $43, $39, $50, $50, $61, respectively. A collection of Soviet astrophysical papers running the gamut from the Phobos project (the publishers may have had to punt on this one since the probes are now defunct), cosmology, supernovae, and particle physics. An enlightening look-see into Soviet astronomy.

COSMOLOGY

Gauge Theory and the Early Universe, edited by P. Galeotti and David N. Schramm, (D. Reidel, 1988), ISBN

90-277-2805-4, hardcover, 382 pages, $98. Another professional-level book that represents the growing link between particle physics and cosmology. Features papers from physicists in the fields of atomic, nuclear, and particle physics; astronomy; and quantum gravity. A highly technical work not recommended for the mathematically faint of heart.

Large Scale Structure and Motions in the Universe, edited by M. Mezzetti, G. Giuricin, F. Mardirossian, and M. Ramella, (D. Reidel, 1988), ISBN 0-7923-0082-3, hardcover, 481 pages, $119. Highly technical proceedings of an international meeting held in Trieste, Italy, in April 1988, on what has been touted as one of the most important fields in astrophysics. *Large Scale Structure and Motions in the Universe* comprises a wide range of rapidly developing topics; consequently this is a thick book. Some of the papers include results from the latest redshift surveys of galaxies, what quasar surveys reveal about large-scale structure, theories of peculiar motions of galaxy clusters, cold dark matter and how large-scale structures might be influenced by its presence, and galaxy formation.

The Two State Universe by Angelo A. Molinaro, (Branden Publishing Co., 1988), ISBN 0-8283-1997-9, softcover, 214 pages, $11.95. For readers with a predilection for "alternative" cosmological theories, we offer (but do not necessarily advocate) *The Two State Universe*. Molinaro asserts that we do not live in a three- or four-dimensional universe, but rather one in which all things have just two complementary states. He extends this two-stateness to concepts such as infinity and its cosmological consequences — plus infinity and minus infinity. Molinaro invokes one of Aristotle's elements, "aether," as a complement of the vacuum of space and explains gravity as the force of attraction between the complements of matter and energy. He believes his theory explains some of the conundrums of physics, including the dual nature of light (waves and particles) and the unified field theory. Like we said, this is an alternative theory.

Particle Physics in the Cosmos, edited by Richard A. Carrigan, Jr. and W. Peter Trower, (W. H. Freeman and Company, 1989), ISBN 0-7167-1919-3, softcover, 224 pages, $9.95. Part of the new "*Scientific American* Reader Series," the text consists of semitechnical, semipopular articles on particle physics and cosmology gleaned from past issues of *Scientific American*. Includes "Dark Matter in the Universe" by Lawrence M. Krauss; "The Large-Scale Structure of the Universe" by Joseph Silk, Alexander S. Szalay, and Yakov B. Zel'dovich; "The Decay of the Proton" by Steven Weinberg; and "The Inflationary Universe" by Alan H. Guth and Paul J. Steinhardt. Contains the same lengthy captions, detailed diagrams, and two-column format as the original articles. However, the book size is smaller ($7\frac{1}{4}$ by $9\frac{3}{16}$ inches) than previous *Scientific American* books.

Proceedings of a Workshop on Optical Surveys for Quasars, edited by Patrick S. Osmer, Alain C. Porter, Richard F. Green, and Craig B. Foltz, (Astronomical Society of the Pacific, 1988), ISBN 0-937707-19-8, hardcover, 378 pages, $32.

Although Pat Osmer wrote in his introduction to this book that the workshop was announced at the last minute, the results were nevertheless first rate. Held at the University of Arizona in January 1988, the workshop endeavored to present a summary of the state of the field of quasar astronomy. The resulting proceedings consist not only of papers given but discussions edited from tape recordings of some sessions. Some of the topics include quasar redshift surveys, luminosity characteristics, gravitational lenses, and quasar clusters.

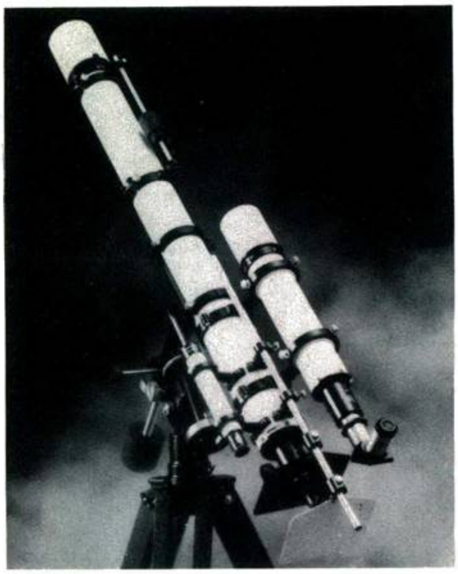
EARTH

Oasis in Space: Earth History from the Beginning by Preston Cloud, (W. W. Norton & Company, 1988), ISBN 0-393-01952-7, hardcover, 508 pages, $29.95.

Origins and Extinctions, edited by Donald E. Osterbrock and Peter H. Raven, (Yale University Press, 1988), ISBN 0-300-04260-4, hardcover, 121 pages, $17.95.

THE SUN

Dynamics and Structure of Quiescent Solar Prominences, edited by E. R. Priest, (D. Reidel, 1988), ISBN 90-277-2833-X, hardcover, 217 pages, $69. The plasma-magnetic field interactions and radiative processes occurring in solar prominences are the main topics of this research text, which is comprised of papers presented at a 1987 workshop in Palma, Mallorca (an island off of Spain's east coast). Chapters deal with the properties and environment of prominences, their magnetic fields, and the formation and structure of prominences. The book contains a selection of black-and-white photographs showing different structures and properties of solar filaments. ☐



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THE UNIVERSE IN YOUR COMPUTER

The Visible Universe for IBM compatible computers, (Parsec Software, 1949 Blair Loop Road, Danville, VA 24541; 1987), standard version, $95, (384K RAM, CGA or EGA/256K graphics, two 360K floppy disk drives); professional version, single user, $295 (512K RAM, EGA/256K graphics, hard disk drive); professional version, institutional user, $495.

The Visible Universe is an intricate and ambitious computer simulation that reproduces the night sky as seen from any location on Earth at any date thousands of years into the past or future. It is probably not a program to use at the telescope, although it can certainly be helpful in preparing for an observing session. I think it will be most useful in an educational setting — a classroom, lab, or home study — but anyone using it will be fascinated and intrigued for many, many hours.

The Visible Universe is menu-driven (the menus are described in the ninety-page manual that accompanies the program). You can identify objects on the screen, find solar system objects, or display catalog and observing information. I ran release 4.7 of the standard version and release 5.0 of the professional version on Zenith model 159 and 286 computers for this review. The program disks were not copy-protected.

The standard version offers three modes of operation and an epoch 2000.0 database containing 9,110 stars from the *Yale Bright Star Catalog* and 8,163 nonstellar objects from the *Revised New General Catalogue of Nonstellar Objects*. The program also displays the Sun, the Moon, all nine planets, the umbra of Earth's shadow, and one additional user-defined object.

The operation mode determines how the sky is displayed. HORIZON-ELEVATION mode shows objects with respect to the local horizon. It displays only about 25 percent of the visible sky at one time, but this mode best recreates the impression of being outdoors. ZENITH mode shows the entire visible hemisphere in the classic "all-sky" format, and RA-DEC mode displays the whole celestial sphere with each object located in equatorial coordinates. The displays appear somewhat coarse when shown in CGA format but are vivid and sharp when you use an EGA graphics card and monitor.

When the program is initially run, you see only solar system objects. You then select additional stars and nonstellar objects for display. You can select by magnitude, spectral type, constellation, or class of object. While this initial selection proceeds relatively slowly, a memory buffer allows rapid redisplay of the elements you've chosen whenever you change the program mode or observing parameters.

The program doesn't draw constellation lines, but it can display only the stars that belong to constellations you have selected. You pick your observing location from a list or enter latitude and longitude. The standard version makes no direct provision for daylight-saving time or the irregular boundaries of time zones, but you can choose your observing time to give local mean or universal time, for example. You can even choose whether to apply precession and proper motion to the sky objects.

A useful feature of the standard version is the REPEAT function. You pick an interval of time (days, hours, or minutes) and the number of repetitions. Stars may or may not be replotted with each cycle, and the screen may or may not be cleared depending on whether you wish to create an "animation" or "tracking" effect. You can show planet disks in their correct relative sizes, and you can zoom in to magnify the view of a narrow area of sky. This lets you simulate solar and lunar eclipses, retrograde motion, occultations, the Sun's analemma, or the motions of the Galilean satellites of Jupiter. Intervals as short as one minute may be used, but the display does not run in real time. Screen updates typically take one or two seconds, growing to five or ten seconds in the worst cases.

This is the standard version; the professional version offers an additional mode, EARTH FROM SPACE. This mode allows you to see Earth as it would appear from an observing site. Coastlines, islands, lakes, cities, and political boundaries may be included. You can display the center line of any solar eclipse and use the REPEAT function to show the changing position and shape of the lunar umbra and penumbra during the eclipse.

The Visible Universe is a powerful and useful tool. Unfortunately, its power is somewhat compromised by the program's limitations. The user interface is difficult to learn and requires considerable practice to use efficiently. (The software needs a quick reference card.) The instruction manual does contain a number of examples and illustrations but is also difficult to use and lacks a comprehensive index or summary of each command.

You sometimes need to impose limits to get pleasing results. For example, although the EARTH FROM SPACE mode offers a zoom factor of up to 20 times, the low resolution of the coastlines database makes any enlargement beyond about 5 times meaningless. At low zoom factors the shading on the Moon doesn't always exactly match the lunar phase unless the disk is enlarged unrealistically; the shading of the planets is sometimes poor at high enlargements.

While the speed of the standard version is satisfactory on a PC/XT at 4.77 MHz, EARTH FROM SPACE should be run on a faster machine. Even at 8 MHz, the medium- and high-resolution databases are too slow for in-class demonstrations, although you can plot them in advance, store them on disk, and quickly reload them.

The standard version is relatively free of bugs, particularly in comparison to version 2.0, which I used first. The only major problem I encountered was a difficulty in centering the cursor on objects such as clusters, nebulae, and galaxies for identification. The program frequently told me that the cursor was not properly centered despite repeated repositioning. Stars and solar system objects did not have this difficulty.

The 5.0 professional version is also much improved over the earlier versions, but some problems are still evident. The program failed on one occasion during apparently normal operation and fairly extensive use. The program had to be rebooted, but the hard disk files were unaffected.

I find mouse operation is best described as difficult and erratic. (I was using a Logictech mouse and software.) If you load your mouse driver before you start the professional version, you can't shut-off mouse operation, not even by deactivating it under the special options menu!

Not all of the special function keys (F1, etc.) appear to be implemented as described in the manual. Finally, the program fails to clear the previous screen when plotting the zenith window from the view menu.

In using various releases of the professional version, I noted that *later* (higher numbered) releases may contain errors not present in earlier ones, *even in functions common to both.* This emphasizes the need for the publisher to take responsibility by providing free correction updates to registered owners. Of course, you should always work only from back-up copies and save your originals for restorations.

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Considering the available features and relative cost, the standard version of *The Visible Universe* is the best choice of the two. The added capabilities of the professional version do not seem commensurate with the increase in cost. — *Raymond C. McNeil*

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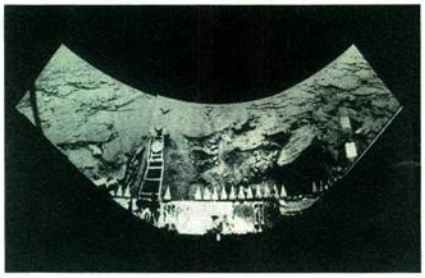

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The slide from *Venera 13* offers two views: one shows the landscape bathed in the actual orange color the spacecraft photographed (sunlight at the surface of Venus is heavily reddened after passing through the clouds), and the other has the orange tint processed out to reveal the lunar gray color the surface would have if we could see it under white light. ☐

Meetings and Events

July 16-24
Spaceweek, Baton Rouge, Louisiana. Sponsored by the Baton Rouge Astronomical Society, Inc. Contact: Mark Stauffer, 17324 Gains Mill Avenue, Baton Rouge, LA 70817.

July 16-24
Spaceweek, Lafayette, Louisiana. Sponsored by the Lafayette Natural History Museum and Planetarium. Contact: Donna Savoie, 637 Girard Park Drive, Lafayette, LA 70503.

July 19-22
Astronomical League National Convention, Spokane, Washington. Hosted by the Spokane Astronomical Society. Contact: Gene Dietzen, P.O. Box 8114, Spokane, WA 99203-0114.

July 20
Return to the Moon Party: 20th Anniversary of the First Moon Landing, Market Square Park, Baltimore, Maryland. Sponsored by the Baltimore chapter of the National Space Society and the Baltimore Department of Parks & Recreation. Contact the Baltimore NSS at (301) 879-3602.

July 28-29
2nd Annual Ozarks Star Party, near Branson, Missouri. Sponsored by the Ozarks Telescope Makers and Amateur Astronomers. Contact: Greg Blount, P.O. Box 165, Cape Fair, MO 65624. Phone: (417) 538-4553.

July 28-29
14th Annual Public Star Night, Saskatoon, Saskatchewan. Sponsored by the Royal Astronomical Society of Canada-Saskatoon Centre. Contact: Jim Young, Box 317, Sub P.O. #6, Saskatoon, Saskatchewan, Canada S7N 0W0.

August 1
Annual Star Party and Picnic, Winchester Canyon Gun Club, Santa Barbara, California. Contact: Clyde Kirkpatrick, P.O. Box 3702, Santa Barbara, CA 93130. Phone: (805) 685-2705.

August 4-6
Mountain Astronomers Rendezvous and Star Party (MARS), Royal Gorge, Canon City, Colorado. Sponsored by the MARS region of the Astronomical League. Contact: Dave Trott, P.O. Box 10814, Denver, CO 80210. Phone: (303) 871-5172.

August 5
Stellafane, Springfield, Vermont. Contact: Stellafane, 60 Victoria Road, Sudbury, MA 01776.

August 5-6
Northwoods Starfest, Fall Creek, Wisconsin. Sponsored by the Chippewa Valley Astronomical Society. Contact: Preston J. Bush, 601 Vine Street, Eau Claire, WI 54703.

August 7-11
Astronomy Camp, Virginia Living Museum, Newport News, Virginia. For children ages 12-14, registration deadline: August 1. Contact: Jon U. Bell, 524 J. Clyde Morris Boulevard, Newport News, VA 23601. Phone: (804) 595-1900.

August 10-13
Rocky Mountain High — The Alberta Star Party 1989, Waterton Lakes International Peace Park, Waterton, Alberta. Hosted by the Lethbridge Astronomy Society. Contact: Registrar, P.O. Box 1104, Lethbridge, Alberta, Canada T1J 4A2. Phone: (403) 381-3744.

August 12
All-Night Star Spectacular and Perseid Meteor Shower Watch, Pokagon State Park, Angola, Indiana. Sponsored by the Astronomical Society of Hillsdale County. Contact: Pat Calligan, 5260 North Dunes Road, Hillsdale, MI 49242. Phone: (517) 439-1295.

August 12
Perseid Meteor Observing, Troy, Michigan. Sponsored by the Astronomical Society of Michigan. Contact: Charles Barnes, 6685 Coolidge, Troy, MI 48098.

August 12
Perseids Party, Cheyenne, Wyoming. Sponsored by the Cheyenne Astronomical Society. Contact: Marcy Flint, 3409 Frontier Street, Cheyenne, WY 82001.

August 12
Stargaze '89, Shadle Park, Washington. Sponsored by the Spokane Astronomical Society. Contact: Bob Lemley, 54140 Cook, Spokane, WA 99223. Phone: (509) 448-9694.

August 16
Lunar Eclipse Observing, Normal, Illinois. Sponsored by the Twin City Amateur Astronomers, Inc. Contact: Donald F. Johnson, P.O. Box 755, Normal, IL 61761. Phone: (309) 452-3866.

August 16
Lunar Eclipse Watch, Portsmouth, Virginia. Sponsored by the Tidewater Community College Astronomical Society. Contact: Dennis Rowley, 3065 Stratford Drive, Chesapeake, VA 23321. Phone: (804) 483-3822.

August 16
Total Lunar Eclipse Observing, Cheyenne, Wyoming. Sponsored by the Cheyenne Astronomical Society. Contact: Marcy Flint, 3409 Frontier Street, Cheyenne, WY 82001.

August 19
Annual Telescope Making Contest, Montreal, Quebec. Sponsored by the La Societe d'Astronomie de Montreal. Contact: Marc A. Gelinas, Cahier Postal 206, Station St. Michel, Montreal, Quebec, Canada H2A 3L9.

August 23-27
Planetfest, Pasadena, California. *Voyager 2* at Neptune events sponsored by the Planetary Society. Contact: Susan Lendroth, 65 North Catalina Avenue, Pasadena, CA 91106. Phone: (818) 793-5100.

August 25-26
Starfest '89, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact: Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5.

August 25-27
3rd Annual Astronomy Rendezvous and Conference, Normal, Illinois. Sponsored by the Twin City Amateur Astronomers, Inc. Contact: Donald F. Johnson, P.O. Box 755, Normal, IL 61761. Phone: (309) 452-3866.

August 25-28
Nova East '89, Fundy National Park, New Brunswick. Sponsored by the Royal Astronomical Society of Canada-Halifax Centre. Contact: Doug Pitcairn, 1747 Summer Street, Halifax, Nova Scotia, Canada B3H 3A6.

August 26
Public Stargaze, Richland, Washington. Sponsored by the Tri-City Astronomy Club. Contact: Thomas L. Page, 1725 Birch, Richland, WA 99352.

August 30-September 3
6th Annual Mount Kobau Star Party, Okanagan Valley, British Columbia. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-size envelope with your request for information. □

Readings and Resources

The Waters of Mars (page 20)

The Channels of Mars by Victor Baker, (University of Texas Press, 1982). This profusely illustrated book examines the Martian channels and valley systems and includes a detailed chapter on the Channeled Scablands.

Viking Orbiter Views of Mars, edited by Cary Spitzer, (NASA Publication SP-441, 1980). A good photo archive of all kinds of Martian landforms, including channels and valleys.

The Surface of Mars by Michael Carr, (Yale University Press, 1981). An excellent general work on Martian geology.

Approaching Neptune (page 30)

The Planet Neptune by Patrick Moore, (John Wiley and Sons, 1988). An entertaining history of the green planet from its discovery through roughly 1987.

"The Uranus-Neptune Dichotomy: The Role of Giant Impacts" by David Stevenson, from *Lunar and Planetary Science XVII*, Part 2, (Lunar and Planetary Institute, 1986). This brief paper presents arguments in favor of the theory that late-impacting objects with huge masses could account for the differences between Uranus and Neptune.

Orion's Stellar Nursery (page 40)

Physics of the Galaxy and Interstellar Matter by Helmut Scheffler and Hans Elsasser, (Springer-Verlag, 1988). A technical survey of interstellar matter that includes significant background on the Orion Nebula.

The Day the Sun Cut Loose (page 48)

The Restless Sun by Donat G. Wentzel, (Smithsonian Institution Press, 1989). An expansive, popular-level perspective on solar sciences that includes three chapters on flares.

The Trail of a Meteorite (page 70)

Find a Falling Star by Harvey N. Nininger, (Paul S. Eriksson, Inc., 1972). An autobiographical account of the golden age of meteorite hunting by America's most renowned meteorite hunter.

Meteorite Craters by Kathleen Mark, (University of Arizona Press, 1987). An historical survey of the still controversial topic of Earth's impact craters.

Meteorites and Their Parent Planets by Harry Y. McSween, Jr., (Cambridge University Press, 1987). A comprehensive survey of the current state of the science of meteorites. ☐

CREDITS

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ANNOUNCEMENT – Exciting new space society founded to increase public awareness and give you a say in the future. Contact the Society for the Advancement of Space Activities (SASA), 1797 Cessna Street, Carlisle, PA 17013.

ANNOUNCEMENT – The Springfield Astronomical Society meets on the last Friday of each month at 7:00 p.m. at the Lincolnland Community College, Logan Hall. Contact Don Walker, 2224 South 13th Street, Springfield, IL 62703. Phone (217) 789-7544 (days or weekends).

ANNOUNCEMENT – The Bucks-Mont Astronomical Association meets the first Wednesday of each month in the farm house at Tamanend Park, Second Street. Pike, Southampton, PA. Phone Dick Sivel at (215) 598-7673.

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WANTED – *Telescope Handbook and Star Atlas* by Neale E. Howard, 1967. Price according to condition. Contact Rex Thompson, 40 Raymond, San Anselmo, CA 94960. Phone (415) 453-3342.

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WANTED – American student seeks correspondence in French with individuals interested in astronomy. Contact Edward Locke, P.O. Box 1883, Columbia, TN 38401.

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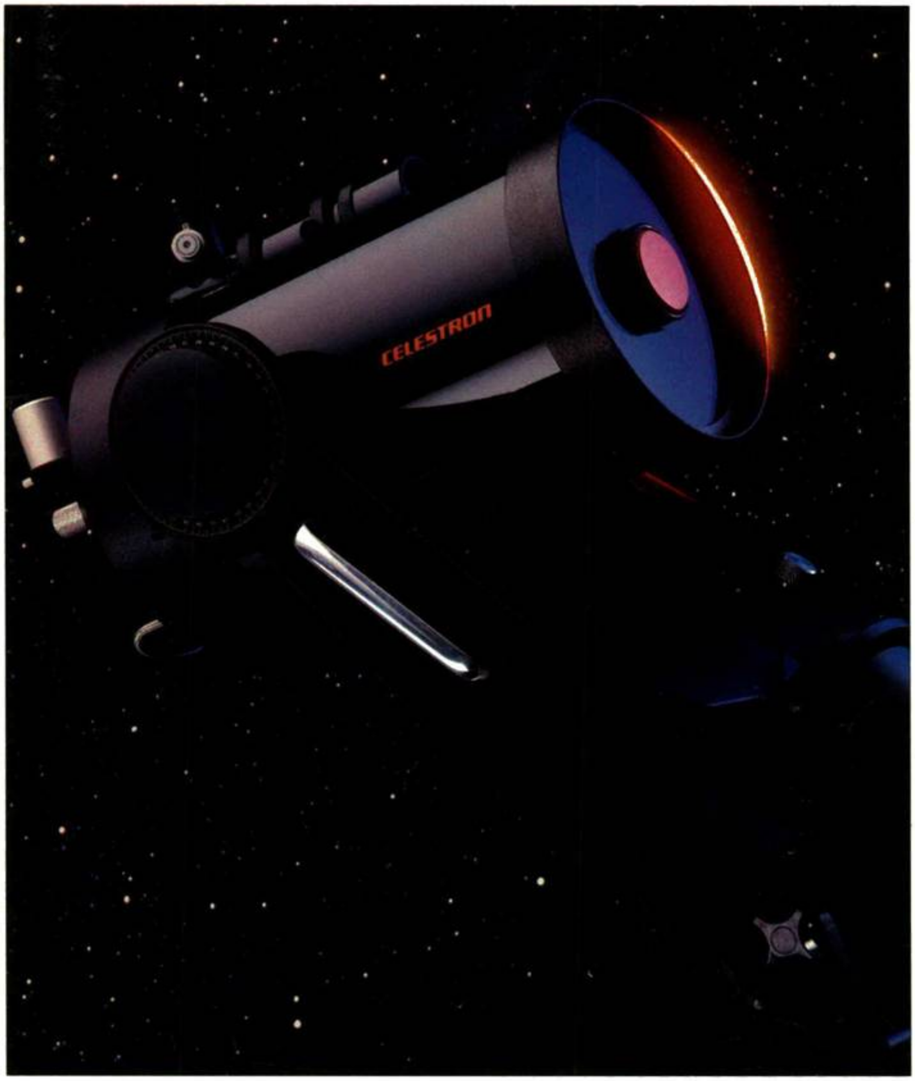

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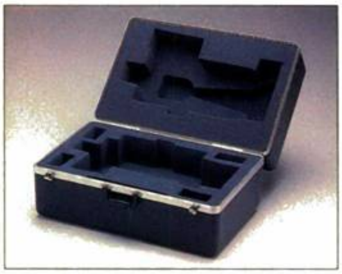

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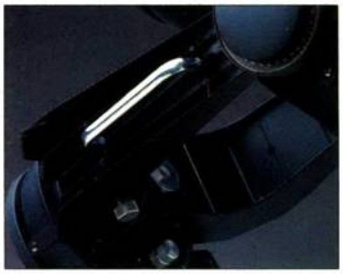

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